CHAPTER 7

MATERIALS FLOWS AND THE SPECIFICATION OF ECONOMETRIC MODELS

The purpose of this chapter is to provide more information about technological and organizational aspects of the industries which process and consume secondary materials. The plan of the chapter is as follows. Section 1 is devoted to defining terms. and describing the categories commonly used in the scrap industry for classifying secondary materials. Section 2 presents a schematic description of primary and secondary materials flows. The emphasis in this section is on identifying the points at which substitution of secondary for primary materials occurs. Section 3 describes in somewhat greater detail the secondary materials flow. In particular, those factors which are relevant to the task of formulating an econometric model of supply and demand are discussed. In section 4 statistical problems associated with estimating long-run supply and demand responses are reviewed with special attention to problems peculiar to modeling secondary materials industries.

I. BACKGROUND

A. Home Scrap

Home scrap is the name given to secondary materials which are generated in production processes and then re-used at the same location, usually in the same production process. Refining and smelting processes which produce copper, aluminum, lead and steel in a first, relatively pure metallic state generate home scrap. Ready accessibility, cleanliness, and known chemical composition make this material valuable to primary metal producers so that there has never been any problem with home scrap going unused or doing damage to the environment. Nor is it likely that changes in metallurgical technology will alter this situation.

Because home scrap is not traded in the marketplace, it is not appropriate to speak of a supply curve for home scrap. There is no price established to which firms respond in deciding how much of their own by-products to recover.

It is conceivable, nonetheless, that the amount of home scrap which gets recycled within a plant mill is dependent upon the price of virgin inputs. If the price of virgin ore were relatively low; primary producers might allow some portion of home scrap which was less easily recovered to go to waste. As the price of virgin ore rose these producers might find it in their interest to spend more on housekeeping functions so as to increase recovery of home scrap and thereby reduce their requirements for purchased virgin inputs and/or the rate at which they used up their own stocks of virgin raw materials. In effect, there is a substitution of labor and perhaps capital for raw materials in response to an increase in the price of raw materials. Theoretically then there might be some relationship between the quantity of home scrap recovered and the price of virgin inputs. It is our impression,however, that this relationship is not a significant one, and therefore is not worth investigating too closely. Available studies seem to concur that primary metal producers presently recover virtually all of their own waste products and would continue to find this an economically efficient practice even with sharply declining prices for virgin inputs.

As long as all home scrap that is physically available is getting recovered, its consumption rate should vary in direct proportion to output of primary metal. This proportion is simply equal to the rate at which by-products are generated in a plant. This proportion may itself be changing over time as newer, more efficient techniques increase production yields. For instance, in the steel industry while traditional ingot practices involve metal losses of 25 percent to 30 percent, continuous casting which eliminates the need for this production stage involves a loss of only five to 10 percent. In the future, if continuous casting becomes more widespread there might be a significant reduction in the generation of home scrap. On the other hand, over the last twenty years there has been an increase in the generation of home scrap caused by a shift in demand toward higher quality steels for which production yields are lower.

These examples point to the need to interpret statistics on home scrap with some care. A reduction in home scrap consumption which is brought about by in innovation such as continuous casting does not result from any lessening of recycling efforts. There are no harmful environmental consequences which accompany such a change since there are still no ferrous residuals flowing into the environment from this sector. Home scrap is still fully recovered. Nor is such a change accompanied by any increase in the rate at which virgin sources of iron are depleted.

It is also improper to infer that such a decrease in quantity of home scrap consumed necessarily makes room for increased opportunities for the consumption of scrap from other sources. For example, while steel furnace inputs (aggregated over all production processes) have traditionally consisted of about 50 percent scrap by weight, this number is not rigidly determined by any technological factors. It is improper to assume that as home scrap consumption varies, compensating changes in the consumption of scrap from other sources leave this 50 percent figure unchanged. A closer look at the various,: technological factors affecting the demand for scrap in different steel-making process is necessary in order to determine the relation between home scrap consumption and the demand for other scrap inputs

Finally, there is the more basic problem of whether it is appropriate to combine home scrap together with scrap from other sources 30 as to obtain a figure defined as the recycling rate. As long as changes in home scrap consumption rates are merely indicative of changes in the path that raw materials follow within a plant, inclusion of home scrap in recycling rates seems somewhat artificial. This is especially so where these internal process changes do not alter the flows of raw materials into or products and residuals out of the plant. The calculation of a recycling rate which includes home scrap can be misleading since many persons would interpret the recycling rate as a measure of the amount of discarded material diverted from the environment back into the production stream. Inclusion of home scrap which never leaves the mill and which would be re-used under any plausible set of economic and technological conditions, overstates recycling thus interpreted.

B. Prompt Scrap

This category includes materials which originate as by-products of one production process and are then shipped off to other plants to be used as inputs to other production processes. Typically prompt scrap is generated in fabricating processes in which intermediate metal or paper products are fashioned into final products. It is then re-used in processes which precede the fabrication stage, perhaps to produce the same intermediate, goods from which it originally came. For example, the production of automobile fenders involves cutting flat rolled sheets of steel into irregular shapes. The trimmings from this operation become prompt scrap, which is returned to steel mills and used as an input in the production of more raw steel.

Prompt is sometimes shipped directly from fabricating plants back to user mills. This is common practice among fabricators who have relatively large quantities of metal or paper to dispose of, especially where the preparation of this material for sale to a mill requires minimal efforts at sorting and processing. Smaller fabricators and those whose by-products require more processing generally sell to scrap dealers who then undertake the necessary preparation and sell scrap to user mills.

While it is thought that, like home scrap, most physically available prompt scrap makes its way back into the production stream, considerably more uncertainty surrounds the estimates of prompt scrap recovery ratios. Several factors make it difficult to know exactly what proportion of available prompt scrap is being recycled; information is lacking both as to the quantity of prompt which is generated and the quantity which re-enters the production process. First, locational considerations make the analysis of this sector a more complicated undertaking than the analysis of the home sector. In the case of home scrap it was possible to determine that all or nearly all available scrap was recycled by observing that existing technology made it feasible for mills, no matter where situated, to recover and consume their own scrap. However, the recycling of scrap from prompt sources involves more than in-plant housekeeping efforts directed at the recovery of relatively uncontaminated by-products. Prompt originates in dispersed locations, most of which are physically separated from the mills to which recycled. material must ultimately return. Transportation costs will vary among different sources and may be a significant part of the total cost of recycling, particularly for those sources which are most remote from mills. This makes it hard to generalize about the costs of recycling prompt scrap from observations on the behavior and the technology of a few fabricating firms. It is often argued that more remote sources of scrap increase their recovery efforts as scrap prices rise precisely because this enables them to bear higher transportation charges.

A second factor which complicates analysis of the prompt scrap sector is that prompt is generated as a by-product in a large number of different production processes. Again this situation is in sharp.contrast to, that prevailing in the home sector. There are only a handful of processes that need to be examined in order to establish the rate at which home scrap is generated and the ease with which it can be recovered.

Determination of the rate at which prompt scrap is generated requires detailed information on the many different production processes that transform raw steel, copper, aluminum, lead, and paper into a wide variety of intermediate and final products.

A third reason that it is difficult to specify the recycling rate for prompt scrap is that even the present consumption rate of prompt scrap cannot be reckoned with any accuracy. The dealers who handle prompt scrap also handle scrap derived from obsolete consumer products and industrial equipment. Often no statistics are kept which give the quantity of material flowing into dealers' yards, broken down according to source. Consequently, prompt scrap is often lumped together with obsolete under the heading "purchased scrap" and it is impossible to know how much of this is prompt and how much is obsolete.

Both as a definitional matter and as a matter of public policy it is not clear whether the recovery of prompt scrap should be regarded as a "recycling" activity which it might be appropriate to encourage through some sort of government action, or regarded rather as an internal production flow. In contrast with home scrap the flow of prompt scrap extends physically beyond the boundaries of the mill. Some prompt scrap is not recovered and this may impose social costs either in the form of disposal costs not fully borne by the firm which generates the scrap, or where proper disposal is not undertaken, in the form of costs associated with a littered landscape. Also, the failure to recover prompt scrap causes the depletion of resources to proceed more rapidly. These factors suggest that recovery of prompt scrap is.properly regarded as a recycling activity. On the other hand much prompt scrap is easily recoverable and therefore so valuable that like home scrap it is automatically recovered without regard to conditions in the scrap market.

C. Obsolete Scrap

This category includes all materials contained in industrial equipment and in consumer goods which are no longer in use. It is also referred to as old scrap (as distinguished from new scrap which consists of home and prompt).

The definitional problems which were encountered with home scrap and prompt scrap do not arise in the case of obsolete scrap. Clearly the recovery of this material constitutes “recycling" in the sense in which this term is ordinarily understood.

The category "obsolete scrap" comprises a considerably more heterogeneous mix of materials than either home or prompt scrap. In a modern industrial society metals and paper are contained in a vast array of different final products. This diversity is reflected in the materials flow of obsolete scrap.

The costs of recovering a particular material from a particular final product are determined by factors such as product design, salvage value of other components or materials in the same product, disposal practices, and the geographical location of the product when it becomes obsolete.

D. Scrap Grades

In addition to the categories discussed above, in which scrap is classified according to its source, there exist a number of scrap grades for each of the materials of interest to us.. Classification into one of several grades comes after scrap materials have received some initial processing such as sorting, separation from the obsolete products which contained them, cleaning, and assembly into easily transportable units. Typically classification according to grade occurs at the point where scrap is sold by scrap wholesalers to user mills such as secondary smelters.

The quality of scrap materials is often closely related to their source (home, prompt, or obsolete), so that particular grades may contain materials which come exclusively from one source. In some cases the specifications for a grade may explicitly exclude materials from one source or another. However, since grade classifications reflect the quality achieved after some processing has occurred it is not unusual to find that a single grade contains materials from more than one source.

E. Organization and Operations of Scrap Industries

Scrap materials are collected and processed by numerous self-employed individuals and small firms. The industry is characterized as competitive. Firms enter and exit the industry quite rapidly in response to changes in scrap prices. Historically capital requirements have been low, though the advent of such mechanical devices as the shredder for scrap steel have increased the costs of entry substantially in some segments of the scrap industry. The scrap industry typically is characterized as labor intensive. Labor, transportation and raw material acquisition costs are the largest components of cost to the industry. Although little has been written on inventory holding behavior of scrap processors, inventory accumulation and depletion in response to anticipated future prices for scrap appears to be an important facet of the scrap metal industries. In the wastepaper industry, physical deterioration of the product over time and the high cost of storage space in relation to product value both limit the desirability of holding large inventories.

Much of the prompt industrial scrap and some of the obsolete scrap is obtained under contract with scrap generators. Although other, marginal sources of supply are available and exploited when prices are high, the existence of these contracts limits the ability of the scrap industry to contract when demand for the outputs of the scrap industry is low.

Following collection, scrap materials are processed in two basic operations: (i) identification and segregation, and (ii) physical preparation. Identification is most commonly made by visual and mechanical measurements of such parameters as color, hardness, attraction to magnets, and spark testing. Although precise identification is required infrequently, it can be made by chemical and spectrographic analysis. The degree of segregation required varies with the source of the scrap as well as the needs of scrap consumers. After identification and segregation, contaminating materials are removed and the scrap is packaged into bundles of a standard size for efficient use by consumers.

II. MATERIALS FLOWS

In this section we. present a general schematic representation of materials flows in the economy. Our aims are twofold. First we wish to convey to the reader some feeling for the wide range of points in the production cycle at which substitution of secondary for virgin materials can occur. Second we wish to give a summary account of the points at which substitution actually does occur for each of the five materials considered in this report.

In some respects the distinction between a group of production processes which supply secondary materials and a group of production processes which demand secondary materials is an artificial one. The movement of secondary materials through the economic system can be better understood as a flow consisting of a series of production processes in which the discarded by-products of production and consumption activities are transformed into final consumer goods or capital goods. All of the intermediate production processes in this flow are involved in both consuming or demanding secondary materials as inputs, as well as in producing or supplying secondary outputs.

All production processes can be placed into one of six broadly defined categories. Three of these categories constitute what we refer to as a secondary materials sector. Production processes in this sector are those which transform secondary material inputs into intermediate and final products. These are production processes in which all or almost all of the important material inputs are from secondary sources. While distinctions which are based on terms such as "almost all" and "important material inputs" may seem a bit vague, they are sufficiently precise for our purposes. The other three categories make up the primary materials sector. This sector includes all other production processes, both those which use only virgin material inputs and those which handle some mix of virgin and secondary materials.

Starting with the secondary sector, the first category is labeled Secondary Materials Collection. This category includes those activities generally undertaken by scrap dealers or scrap processors such as collection, dismantling of obsolete products, sorting, cleaning, and the breaking of large pieces of scrap or the consolidation of small pieces into forms which are more. convenient for handling purposes. In general these are activities which alter only the physical characteristics of secondary materials.

Following this comes a category which is denoted Secondary Materials Processing. Activities in this category represent a continuation of those in the preceding category insofar as the object is still to reduce a diverse collection of material inputs in somewhat contaminated form, to a relatively small number of outputs of purer and more uniform quality.

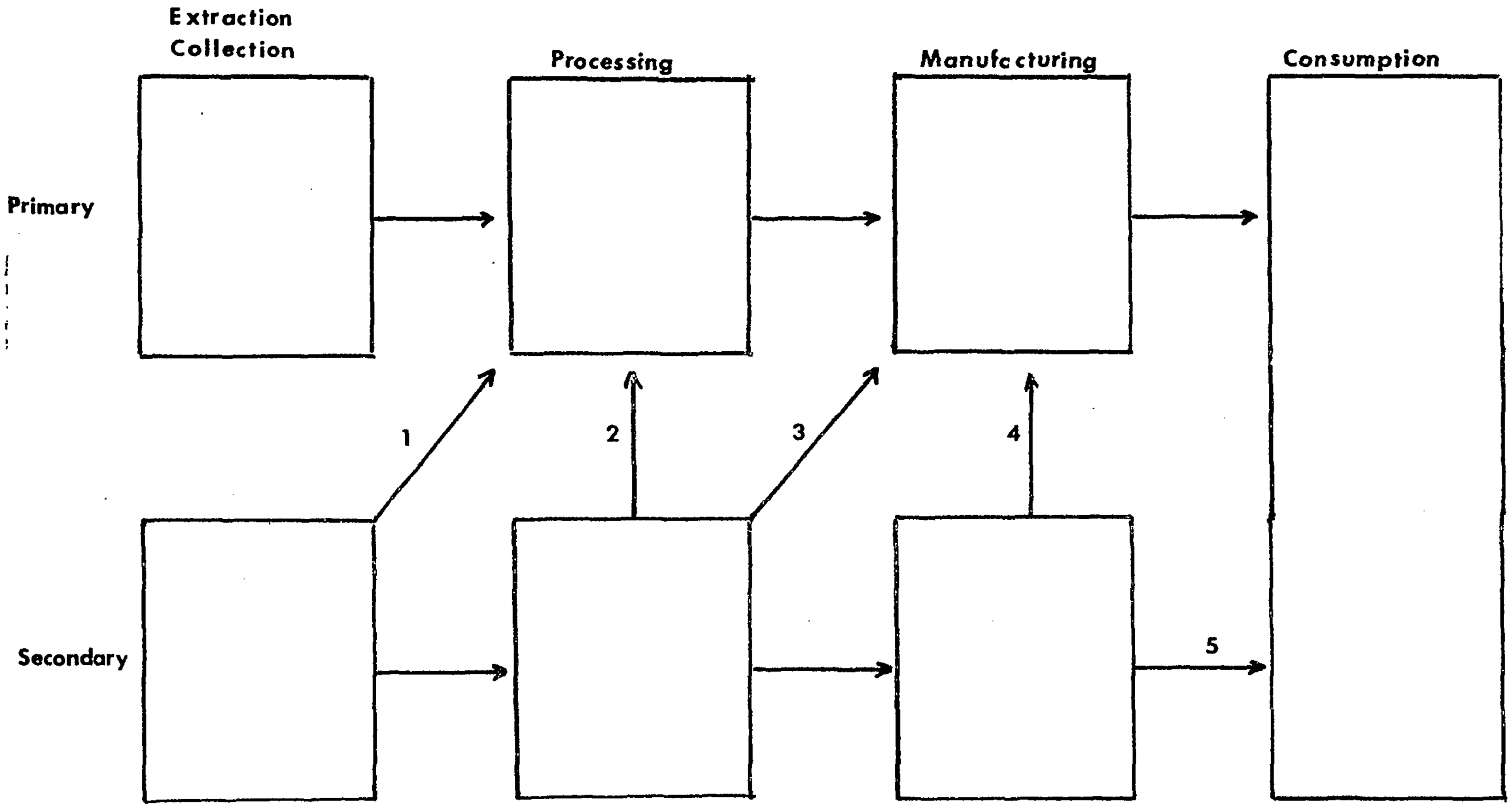
These first two categories are distinguished from one another by the fact that activities in the latter group are substantially more complex involving chemical as well as physical alteration of the material inputs. Typical processes in this category are the operations of secondary smelters of non-ferrous metals. These facilities consume processed scrap which they have purchased from dealers or sorted and processed themselves. Inputs are melted down, various contaminants are driven off, and an output of secondary metal ingot is obtained.

Following Secondary Materials Processing comes Secondary Manufacturing. Manufacturing operations are defined as those processes in which raw materials which have been refined into a relatively pure form are shaped or combined with one another into a variety of intermediate goods and ultimately into final products. This category is very much smaller than the two preceding ones since most secondary materials get combined with some primary materials at the manufacturing level and are thus reabsorbed into the primary sector. Very few final products are manufactured from 100 percent recycled materials so that the secondary materials flow is rather insignificant as it enters the consumption sector.

The activities in the primary materials sector can be divided into three categories which parallel those in the secondary sector. Analogous to scrap collection activities are operations such as mineral extraction and timber cutting in which virgin materials are severed from their. natural environments. As with secondary materials, it is convenient to include in this category those initial stages of physical processing such as screening or concentration of ores which are undertaken at the same site. Following this come Primary Materials Processing. These operations are often somewhat more complex and more capital and energy intensive than counterpart secondary processing operations. This is SO with most metals, where primary processing may require the separation

FIGURE 7 - 1

MATERIALS FLOWS



of metal from ores that are relatively low in metal content, while secondary processing involves refining away minor impurities from metals which have already been separated from their ores. Primary Manufacturing includes all manufacturing processes except those few in which all or nearly all materials inputs come from secondary sources.

The numbered pathways indicated on the diagram show the points at which secondary materials substitute for virgin materials and virgin based products.

Scrap materials which need only be collected, and perhaps physically altered, to become suitable as inputs to primary production processes move along pathway #1. Generally this material is of high quality to start with, most likely originating as home or prompt scrap. It must be clean and its chemical composition must be known with a great degree of certainty. An example of a secondary material which follows this path is that portion of scrap copper which is consumed in primary smelting and refining operations along with ores, concentrates or primary blister copper. Another example is that portion of iron and steel scrap which is consumed in basic oxygen furnaces and open hearth furnaces along with pig iron to produce carbon steel.

Some scrap materials become acceptable as inputs to primary materials processing operations only after they have received somewhat more extensive treatment. These materials go from scrap dealers to secondary processors and then along pathway #2 to the primary sector. An example is waste paper which is de-inked and re-pulped before being used as an input which substitutes for virgin pulp in the production of tissue.

Much of the scrap which enters secondary materials processing facilities is converted into intermediate products that compete directly with virgin based products at the manufacturing stage. This situation is represented as pathway #3 in the diagram. Some amount of all the materials we are Considering re-enter the primary materials flow in this way. Lead from secondary smelters and refiners is indistinguishable from primary lead. Both products enter as inputs to the same manufacturing processes. Some scrap copper is smelted and refined into secondary grades that are identical to grades of primary copper.

The case of steel is slightly different. Electric furnaces which consume only scrap are essentially secondary materials processing operations, despite the fact they are sometimes run by the same firms which operate furnaces that consume mostly virgin inputs. Unlike copper and lead, where primary and secondary refined metals are virtually identical, the output of electric furnaces is generally limited to high alloy grades of steel, so that competition between primary and secondary products is confined to only part of the market for raw steel.

Pathway #4 represents the situation where scrap is processed into secondary raw materials which remain in the secondary sector through the initial stages of manufacturing. Intermediate goods from the secondary manufacturing sector are then combined with other intermediate goods from the primary manufacturing sector to form final products.

The examples we have in mind here are the aluminum, iron, steel, brass, and bronze foundry industries. These are characterized as secondary manufacturing industries because all or nearly all material inputs are produced from scrap. Most of the outputs of these industries are intermediate goods,such as engine blocks, which are used as components in a wide variety of final products. Some foundry products are themselves final goods and are therefore properly classified as following pathway #5.

Pathway #5 represents the situation where scrap inputs are processed and manufactured into final products made up entirely of secondary materials. The best known example of a product which fits into this category is paper which is made from 100 secondary fibers.

III. FACTORS AFFECTING MATERIALS FLOWS

In order to understand how changes in technology and/or public policy are likely to affect the rate of secondary materials throughput,one needs something more than just a general description of the entire materials transformation process. A somewhat narrower focus is called for which gives detailed information about factors affecting the rate of flow of secondary materials at specific points in the flow process. In this regard economic concepts of supply and demand can be brought into play. It is often useful to choose a particular point in the materials flow at which the preceding production activities are viewed as supplying secondary materials and the production and consumption activities which follow are viewed as creating demand for secondary materials. One then attempts to identify parameters which affect the rate at which producers are willing to supply secondary materials, and parameters which affect the rate at which other producers or final consumers wish to consume secondary materials. Taken together these two sets of factors should determine the flow rate which actually prevails at this point. If in addition one is able to relate changes in public policy or technology to changes in the values of one or more of the parameters influencing supply and demand it is then possible to predict the effect upon the recycling rate of specific changes in technology or public policy.

The question which immediately arises is what are the important points in the flow to which our attention should be directed. Most discussions of recycling treat as supply activities those engaged in by scrap dealers and those engaged in by individuals or firms that prepare or upgrade the secondary materials which they themselves generate. These activities include such things as collecting scrap from the environment, cleaning it, and sorting it. In general they can be characterized as activities which alter the physical properties or alter the location of scrap materials. All production and consumption activities which come later in the materials flow are placed on the demand side.

In some respects this is an appealing way to separate supply from demand. It focuses on the first point where it is possible to measure the flow of secondary materials using standard economic concepts. Prior to this point the secondary flow is comprised of a heterogeneous mix of materials which vary widely with respect to location, physical quality, and chemical characteristics. Prices or values can be assigned to such scrap materials only on a highly specific basis which takes account of the distinctive physical, chemical, and locational attributes of particular quantities of scrap.

Once scrap has been processed by dealers, however, the flow of secondary materials can be neatly broken down into a manageable number of homogeneous product classifications conforming to the scrap grades traded in the market. Prices exist for specific grades and price indexes can be constructed for categories which represent the aggregation of several grades.

While a supply equation for secondary materials at the stage where they have been collected, sorted, and cleaned is useful for some purposes, it may be that this is not the most appropriate point in the secondary materials flow to analyze supply and demand. To some extent the choice of a point at which to measure supply and demand is dictated by what is being studied. For purposes of this study the rate of secondary throughput relative to virgin throughput is of interest so that it is important to look with some care at those points in the flow where there is actual or potential substitution between virgin and secondary materials.

Unfortunately it is difficult to generalize about all of the consumption and production processes in which primary and secondary materials substitute for one another. The stage at which actual or potential competition occurs, differs among various materials. For instance,a considerable amount of scrap iron and steel goes directly from the scrap dealer into steel furnaces that simultaneously consume both scrap and virgin iron bearing inputs to produce raw steel ingot. Old.scrap aluminum, on the other hand, goes to secondary smelters where it is made into secondary ingot, a product which substitutes at a later production stage for primary ingot made from virgin aluminum.

Even for a single secondary material one observes substitution occurring at a number of points. In the case of copper, some scrap which has only been sorted and cleaned is used as an input at primary copper smelters. In this use it substitutes for virgin copper bearing materials at a relatively early stage in the production of refined copper. Other copper scrap is upgraded further at secondary smelters and secondary refiners These firms transform raw scrap copper into either secondary refined copper,which is identical to refined copper produced at primary plants, or into alloy ingot which substitutes for refined copper in some uses.

Besides technical possibilities for substitution which constrain opportunities for augmenting the flow of recycled materials, a host of other factors affects the rate at which scrap is collected and processed. The remainder of this section is devoted to a discussion of two of the more important recycling parameters which can be incorporated in econometric models of the scrap industry. These factors are scrap availability and the point in the materials flow at which to specify the model. Specification of other important variables, such as price, industrial activity in various sectors, and primary material production, is considerably less difficult and is left to the separate analyses of scrap industries which follow this chapter.

A. Availability

It is useful to think of the materials which have become available for recycling as a resource base for the scrap industry. The level of effort expended in exploiting this resource base is determined by the prices offered for processed scrap. The actual quantity of scrap which is recovered through these efforts depends upon prices. If the resource base were stable over time there would be no reason to explicitly include it in our analysis. However, it does change over time and for this reason econometric models of the supply of scrap materials must include some index which represents those changing aspects of the resource base which affect the costs of scrap recovery.

In order to design an index which measures the size and quality of the resource base it is useful to look first at the forces which cause it to change over time. Basically there are three such forces: flows in, deterioration, and flows out. Scrap materials enter the stock as final products wear out and as industrial by-products are generated. Materials which have entered the stock may deteriorate or become less accessible as they remain there for some time. And finally materials are removed from the stock at such time as their recovery becomes economically profitable.

Materials become available for recycling as final products wear out and are retired from service and as residues are generated in industrial processes. The flow of worn-out final products depends upon the quantity of final products produced in earlier periods and the rate at which they decay. Although the production of different final products normally is recorded quite accurately, a large variance in the rate of decay among products and also within any single product category limits the reliability of final goods production statistics from prior periods as a measure of the current flow of obsolete materials into the resource base of the scrap industry. An important exception to this general rule occurs when the time-in-use for a product is short and/or has a relatively small variance. Replacement storage batteries provide an example of this phenomenon, since most batteries lose their ability to hold an adequate charge after a period of service of from 24 to 36 months. Newsprint is another example where time-in-use is quite short and recent production statistics provide a good measure of current generation of obsolete scrap.

Nearly all prompt industrial scrap is recycled regardless of the price of scrap. This is a reflection of the fact that prompt scrap is normally collected under contract and once collected its sale at any positive price is preferable to paying for its disposal at a municipal dump. The primary determinants of the flow of prompt scrap are current or nearly current indexes of industrial activity in product fabricating and manufacturing operations.

Once materials are available for recycling they begin to deteriorate and continue to do so until they are collected by scrap dealers. Hence, the longer the lags between the generation of materials available for recycling and the collection and processing of these goods, the less of each good that is available for recycling.

The third and final way in which the resource base may change over time is through the removal of materials which are recycled. This flow of materials out of the scrap reservoir is particularly important for purposes of measuring the availability of scrap. The assumption that scrap dealers behave rationally guarantees that the most accessible materials are always removed first. Therefore, depletion of the resource base not only diminishes the overall quantity of scrap, it also lowers the quality of the resource base so as to raise the cost of obtaining scrap at the margin.

If there were no materials entering the resource base then the marginal costs of obtaining raw scrap would rise with each successive unit of scrap removed. It would then be appropriate to include cumulative removals of scrap from the reservoir as an independent variable in the supply equation.

Since the scrap reservoir is constantly being replenished, however, such a model would not be correctly specified. One possible situation is that flows into and flows out of the reservoir achieve a balance such that a quantity q_o can be supplied each month without causing any shift in the marginal cost curve. If there were a temporary increase in scrap demand so that for some months quantity q_1 (greater than q_o) was supplied, all other flows remaining constant, then the initial equilibrium would be disturbed. The resource base would be depleted for some number of succeeding months during which the marginal cost curve would shift upwards.

Once demand settled down to its normal level, flows of scrap into the reservoir would build it up again,thereby restoring the equilibrium marginal cost conditions.

This scenario suggests that it is removals of scrap during recently preceding months rather than cumulative removals which are related to the marginal costs of obtaining scrap. The most direct way of capturing this relationship would be to use a lag structure on the dependent variable as a proxy for the availability of scrap. This treatment would take account of materials flows out of the reservoir and would account in a rather crude way for flows of scrap into the reservoir. However, variations in the flow of scrap into the reservoir would not be handled very adequately. For instance, it might happen that during a period in which an unusually large amount of scrap was supplied (quantity q_1), there was also an unusually high rate of flow of raw scrap materials into the reservoir. In this case a proxy based on lagged quantity might indicate a significant deterioration in the reservoir even though materials flows into the reservoir left it unchanged.

In order to minimize the chance of this sort of error lagged scrap. prices can be used in place of lagged quantities. The idea here is that past prices give an indication of how difficult it was to obtain marginal units of scrap in preceding periods. If prices were high,then scrap retrieval efforts must have been carried to the point where the last units of scrap to be recovered were fairly inaccessible. Thereby the reservoir must have been left relatively depleted. Conversely,if prices were unusually low,then even scrap which was reasonably accessible would have been left and raw scrap would remain relatively abundant. For both of these hypothetical cases, the lagged quantity of scrap supplied might have been high, average, or low, depending upon the rate at which raw scrap entered the reservoir during these months.

Obviously lagged prices are still not the perfect proxy. Extremely sudden changes in the rate at which scrap flows into the reservoir could lead to a situation in which this proxy gives a distorted picture of scrap availability. Imagine a situation in which a large fleet of aircraft is rendered available for recycling through retirement of the planes. Even if the price of aluminum had been high in prior periods and collection of relatively inaccessible materials had taken place, there may be an abundance of scrap aluminum in the present period. While not a perfect proxy it is felt that past prices give the best practical measure of the extent to which the reservoir has been depleted.

B. Model Specification

The stage at which to establish an econometric model of an activity which involves several stages of processing is quite arbitrary. At any point in a materials flow a line of demarcation may be interposed with the flow preceding the line termed supply and the flow beyond the line termed demand. In many cases the processing stage at which the model should be constructed is obvious once the desired outputs of the model are stated. For example, if one desires information on the impact of demand shifts for final outputs on market prices, one would estimate demand and supply equations for final outputs. In other situations the absence of reliable data precludes the estimation of market relationships. This report is concerned with the manner in which taxation in the virgin material sector affects flows through the secondary materials sector. Accurate estimation of these effects is rendered difficult because we are studying a second-order phenomenon and because the long-run impact is likely to be quite different from the short-run responses that are observed as market prices fluctuate.

Inasmuch as we must estimate second order effects to determine the impact of primary material taxation on secondary material use, the econometric specification must establish a link between virgin and scrap material use. There are two basic alternatives for connecting the two sectors. The first is to identify existing points of substitution and estimate market relationships at these points. For example, scrap steel and pig iron freely substitute in some steel making processes. Thus an econometric model of the steel making industry would be useful in measuring substitution and competition between scrap steel and virgin based materials. The second alternative is to assume long-run substitutability at some point as materials flow through the processing, fabricating, and consumption sequence. For example, although scrap lead and virgin lead concentrates are processed separately to yield sets of final outputs which differ considerably in composition, final outputs of the two sectors are virtually indistinguishable and should substitute freely in almost all end uses. Thus an econometric model of the lead industry which specified a single demand equation for all final lead outputs and separate supply equations for the virgin and scrap sectors would be adequate for our purposes.

A second critical aspect of model specification concerns the type of data to be used. Within the constraints of data availability we normally had the option between annual and monthly data. Annual data would be most reliable and appropriate for the estimation of the long-run price elasticities of demand and supply of interest in this study. Two factors limited our use of annual model specifications. First was the problem of identification of the separate equations in each model, given that virtually the same set of variables appears in both supply and demand evaluations in many instances. The second factor was data consistency. Many of the crucial data series have been kept on a consistent basis for relatively short periods of time. Periodically the method of computing a statistic is abruptly revised and often no formula is provided for the integration of the separate series into a consistent whole. Often we were lucky to find ten consecutive years of data which had been computed by the same method. In a time series equation with two or three independent variables, ten observations are far too few with which to make accurate parameter estimates.

Identification problems deserve further comment. When identical variables affect both supply and demand, a regression of equilibrium quantities on this set of variables may produce significant coefficients, but it may be impossible to determine if one has a demand equation, a supply equation, or a combination of the two. For example, two variables, price and current industrial activity in product fabricating, may be the principal determinants of demand for the output of a scrap industry.

The supply of obsolete scrap is likely to be affected mainly by the price of scrap, and the supply of prompt industrial scrap is most strongly affected by recent activity in some of the same fabricating sectors which are a source of demand. The lag between fabricating activity being a source of demand and a source of supply is normally a few months at most. Therefore, annual data for both supply and demand equations would be identical, or nearly identical,even if one could make the two of three month adjustment in the fabricating series for the supply equation. On the other hand, the specification of a monthly model permits the use of distinctly different data sets for demand and supply.

In the separate industry analysis which follow in chapters 8 through 12 we used the following specifications.

Table 7-1. INDUSTRY SPECIFICATION

Industry	Stage Where Substitution Is Modeled	Observation Interval
Steel	Inputs to Steel Production	Monthly
Paper	Inputs to the Production of Tissue, Newsprint, Paperboard, and Corrugated Medium	Monthly
Copper (a)	Inputs to Production of Refined Copper	Monthly
Copper (b)	Final Outputs	Annual
Lead	Final Outputs	Annual
Aluminum	Inputs to Non-integrated Mills	Monthly

IV. LONG-RUN PARAMETER ESTIMATION

For purposes of this report we are most interested in the long-run supply elasticities for scrap materials. This is because we wish to predict how much the rate at which scrap is supplied will rise following first, a lasting increase in its price,and then,a period of time sufficiently long for all adjustments to the new price to be worked out. Therefore, two questions should be addressed right at this point: 1) Does the analysis of monthly data produce long-run parameter estimates, and 2) assuming it does not, what relationship is there between our estimated elasticities and the true long-run elasticities?

The answer to the first question is that estimated annual equations are far more likely to yield long-run parameters than would similar equations estimated with monthly data. In order to estimate directly a long-run supply equation one would have to observe changes in the quantity of scrap supplied which accompanied relatively long-lived changes in the price level of scrap. Monthly equations which are developed for scrap paper, steel, copper and aluminum are based upon responses of scrap dealers to monthly variations in the price of scrap.

The answer to the second question is not so straightforward. There are a number of reasons why one might expect the elasticities we have estimated based on monthly data to differ from the long-run elasticities. Unfortunately, it is the case that some of these reasons suggest that our estimated elasticity is lower than the long-run elasticity while others suggest just the opposite.

To begin with we examine the standard economic distinction between the short-run and the long-run. The short-run is defined as a period of time in which at least one factor of production is fixed. In the long-run all factors can be varied.

Assume that all firms in an industry are initially in a long-run equilibrium position. Every firm consumes all inputs and produces output at rates which minimize its average total costs; output price is p_o and firms. produce at an aggregate output rate of q_o. It is generally accepted that the short-run supply response to an increase in output price from p_o to p_1 will be less pronounced than the long-run response.

Over a period of, say, a few months, a firm may increase its output by hiring more labor or operating with extra shifts. However, it must make do with its existing physical plant. As the firm strains to produce at a rate which is beyond what its plant and machinery were designed for, marginal production costs may begin to rise very rapidly. Finally, there may be an absolute constraint upon the rate at which outputs can be produced.

Over a longer period of time a firm has the opportunity to expand its physical plant. It no longer must operate plant and machinery at a rate which is technologically inefficient in order to produce a large quantity of output. Once new capital stock is in place, the short-run marginal cost curve shifts outwards, so that the output can be expanded further before reaching the point where the marginal costs of producing additional output exceed the output price.

Applied to our analysis of the scrap industry, this line of argument would lead us to expect the long-run supply elasticity to be greater than our estimated elasticity which is based on monthly data. Scrap dealers may have limited yard space, shredder capacity and baler capacity which cannot be expanded within a single month, but which can be expanded over the course of a year of two. Also over a longer period of time, it is possible for facilities to be opened in fringe areas where the relatively low volume of scrap generated is only sufficient to make scrap recovery a profitable venture when scrap prices are high.

A second reason why one might expect the long-run supply elasticity to differ from estimated elasticity goes back to the notion that one of the inputs to the scrap production process, namely raw scrap, is drawn from a depletable resource base. Again, assume that the scrap industry is initially in equilibrium supplying quantity q_o at price p_o and that an increase in demand drives the price up to p_1. We know that cost minimization by scrap dealers implies that the most accessible scrap inputs are collected first. At the higher price p_1 scrap dealers are able to increase the quantity supplied to q_1 by extending their collection efforts to less accessible sources of raw scrap.

It may be the case that a price increase which lasted for only one month would be accompanied by a relatively large increase in the quantity of scrap supplied as accumulations of scrap which were just sub-marginal at the lower price are exploited for the first time. After several months of high prices,however, these sources may be exhausted depending upon whether the rate at which they are exploited exceeds the rate at which they are being replenished. If these sources of scrap are being run down,the rate at which scrap is supplied at the higher price must ultimately decline somewhat,perhaps to a new equilibrium level q_2. This new rate of supply can be sustained indefinitely because the flow of marginally accessible materials into the scrap reservoir is in balance with the rate at which such materials are removed. Prolonged periods of high scrap prices may cause the resource base to become depleted, thereby shifting the marginal cost curve upwards. This is exactly the effect which we are attempting to model when we use lagged price as a proxy for the quality of the scrap reservoir.

A third reason why our estimated elasticity might differ from the long run elasticity relates to the ability of scrap dealers to hold large inventories and thereby function as speculators. After retrieving raw scrap from the environment or purchasing loads of scrap from fabricators for as low a price as possible, scrap dealers are prepared to hold these materials for many months if necessary in order to obtain as high a price as possible. If scrap dealers perceive scrap prices to be abnormally low,inventories will accumulate. If they perceive prices to be abnormally high,they will attempt to sell as much scrap as possible in order to make a quick profit by driving down inventories.

In order to understand why this short-run phenomenon can cause our estimated elasticity to exceed the long-run elasticity we again postulate an initial equilibrium in which quantity q_o is supplied at price p_o. Demand increases drive the price up to p_1 and scrap dealers respond to this price by increasing the quantity supplied to q_1. The increase in quantity supplied, q_1-q_o, is met in two ways. Scrap dealers may intensify their collection efforts and begin recovering scrap which was not quite profitable at price p_o. Or they can begin supplying processed scrap at a faster rate than they are collecting raw scrap hence drawing down their inventories. Dealers are likely to engage in this latter kind of behavior if they perceive price p_1 to be only temporary and expect that the price will settle down again to p_o in the near future. If it turns out that p_1 is maintained, the practice of supplying scrap out of inventory will finally cease. The price p_1 will come to be perceived as the new long-run equilibrium price,and dealers will no longer see any advantage to drawing down inventories in order to sell as much scrap as they can immediately. In addition, even if after several months scrap dealers still expect the price p_o to be restored,they cannot continue to draw down inventories indefinitely.

From the above discussion it is not clear whether our estimated elasticity is greater than or less than the long-run elasticity. The fact that our observation period is too short to allow for adjustments in capital stock would tend to cause the estimated elasticity to be lower than a longer-run elasticity. On the other hand the fact that even relatively large changes in the quantity supplied during a single month may not significantly affect the availability of scrap while lasting changes will have an effect, indicates that the estimated elasticity may be higher than the long-run elasticity. Also, the fact that large monthly changes in the quantity of scrap supplied may simply represent adjustments in inventories tends to indicate that our estimate may be too high.

The question remains, then, whether we can correct for any of these biases. The equation for scrap steel, for example, contains a proxy for the availability of scrap in the environment. Conveniently enough, this proxy happens to be based upon lagged prices. Thus,a lasting price change is felt in this equation, not only as a change in present price, but also as a change in the proxy variable. By plugging into the equation a postulated permanent one percent change one can compute an elasticity that takes account of some longer-run effects. We need merely sum the coefficient for present price and the coefficient for lagged prices and compute the revised elasticity.

Still it is open to question whether this new elasticity estimate is any closer to the true long-run elasticity. If, as we have implicitly assumed, the proxy P_{lag} only captures the long-run effect of dwindling scrap availability, our problem is not solved. In this case the revised elasticity estimate does not take account of the potentially offsetting effects of long-run capital stock adjustments and short-term inventory adjustments.

What is more likely to be the case is that our proxy variable captures each of the three adjustment effects at least to some extent. However, since we do not know whether in the case of scrap steel, four months is sufficient for all three effects to work themselves out completely, it is still difficult to say with any confidence whether the revised estimate is higher or lower than the long-run elasticity. Our conjecture is that while four months of high prices is long enough for inventories to become run down and for the availability of raw scrap in the environment to decline, it is probably shorter than the period of high prices which would be necessary both to convince scrap dealers to undertake capacity expansion and to allow these expansions to actually be completed.

CHAPTER 8
IRON AND STEEL

The iron and steel industry ranks first in domestic metal production. Historically, 50 percent by weight of the iron bearing inputs used in the production of iron and steel have been scrap. It is important to note however,that only about one-fifth of this has come from obsolete iron and steel products. Also, as will become apparent below this proportion given for obsolete scrap is only an approximation. Unlike copper, aluminum and lead where industrial scrap consumption is clearly disaggregated into new scrap and old scrap, a major problem in analyzing the scrap iron and steel industry is determining what proportation of the scrap consumed during any given period comes from recycled obsolete products.

In this chapter we investigate the factors which determine the amount of scrap,and in particular obsolete scrap, which gets used in the production of iron and steel. Our ultimate aim is to predict what effect tax induced changes in the cost of obtaining virgin iron might have upon the rate at which obsolete scrap gets recycled. In section I we review the details about sources and grades of scrap iron and steel. Then we discuss the technological factors which determine the costs of retrieving scrap from the environment and the factors which affect the ease with which scrap can be used as an input in various iron and steel production processes. In section II we formulate an econometric model of the supply and demand for obsolete scrap. In section III we present and interpret the results of our econometric work. Finally, in section IV we use these results to predict the impact of tax induced changes in the price of virgin iron bearing inputs upon the rate at which obsolete iron and steel scrap is recycled.

I. MATERIALS FLOWS AND INDUSTRY DESCRIPTION

A. Sources

Iron and steel scrap is classified by source into three categories: home, prompt and obsolete.

(1) Home Scrap

Home scrap is generated at steel mills in the production of raw steel ingot and semi-finished shapes such as slabs, billets, and sheet. Ready accessability, cleanliness and known composition make this material valuable to steel makers so there has never been any problem with home scrap being discarded into the environment.

Historically home scrap has constituted about 30 percent of the total metallic feed to steel furnaces. In the event that continuous casting processes become more widely adopted this percentage will likely drop. Smaller amounts of home scrap would be recycled, simply because smaller amounts would be generated in the first place. Such a change would have no effect on either the rate at which ferrous residuals were released into the environment or the rate at which virgin sources of iron were exploited. More widespread adoption of continuous casting would increase the effective capacity of the steel industry. This could affect input use indirectly.

(2) Prompt Scrap

The category prompt scrap is composed of ferrous materials which originate as by-products in steel fabrication processes. For example, the production of automobile fenders involves cutting flat rolled sheets of steel into irregular shapes. The trimmings from this operation become prompt scrap. While it is known that most physically available prompt scrap makes its way back into the steel production process, there is some uncertainty about the exact percentage of available prompt which gets recovered. A study by the Battelle Institute estimated that 90 percent of available prompt presently gets recycled (Regan, McCleer).[1] This statistic permits an inference that scrap flows from this source could conceivably expand by slightly more than 10 percent in response to a change in the price of virgin iron. However, the 90 percent statistic and,consequently, this inference are open to question for the reasons discussed in Chapter 7 and elaborated upon below.

Determination of the rate at which prompt scrap is generated requires detailed information on the many different production processes that transform raw steel into a wide variety of intermediate and final steel products. Those statistics which do exist are only estimates based upon surveys conducted by the Battelle Institute.[2] The last complete survey was conducted in 1954 and some limited efforts have been made to update this work and apply it to the period for 1960 to 1970. However accurate these statistics may have been for the periods during which they were compiled, continuing changes in numerous production techniques, final product specifications and final product mixes introduce the possibility that these statistics do not accurately represent the present situation.

The quantity of prompt scrap recycled in any given period is also difficult to measure because existing statistics do not permit an accurate disaggregation of materials handled by dealers into prompt and obsolete categories.

(3) Obsolete Scrap

Obsolete scrap is iron and steel which is contained in industrial equipment and in consumer goods, which are no longer in use.

Such factors as product design, salvage value of components or materials other than iron and steel, disposal practices, and the geographical location of obsolete products affect the costs of recycling the iron and steel which they contain. Structural components of buildings, railroad equipment, industrial equipment and ships are generally the most readily accessible sources of obsolete iron and steel scrap. Iron and steel which is contained in these objects can be recovered and processed into a usable form relatively easily. In most cases iron and steel contained in these objects can be separated quite readily from other non-ferrous, components. This cuts down on scrap processing costs. These objects provide high concentrations of iron and steel in relatively limited geographical areas. The large absolute size of ships, buildings which contain structural steel, and railroad locomotives guarantees that large quantities of iron and steel are present at a single location. Individual pieces of industrial equipment are generally found in factories of some sort and so are surrounded by other pieces of equipment, and other potential sources of scrap iron and steel scrap. The factor of geographical concentration cuts down on transportation costs. Finally some of these objects, particularly railroad locomotives and industrial equipment, contain components or material other than scrap iron and steel which have some value. Money which is obtained from the sale of these components in effect covers part of the costs of obtaining the scrap iron and steel.

Automobiles are somewhat less attractive as a source of iron and steel scrap.[3,4] This can be accounted for in terms of some of the factors listed above. Obsolete automobiles are not always present in large concentrations. Those which are, namely those which end their useful lives close to large population centers, tend to be recycled. However, the costs of recycling automobiles which are abandoned in rural areas are often prohibitively high because of high transportion costs. Like railroad locomotives and industrial equipment, obsolete automobiles do contain valuable parts which are removed from the auto hulk before it is processed as scrap. However, because automobiles are small relative to, say, railroad locomotives,the value of parts is also relatively small, so that the combined value of parts and scrap steel is not always sufficient to cover the costs of transporting an abandoned automobile to a scrap yard, dismantling it, and processing it into usable scrap.

Less valuable still as sources of scrap are household appliances. Like automobiles such objects may become locationally dispersed upon being discarded. They end up in backyards or in landfills. In general they are even smaller than automobiles so that the effort involved in collecting, dismantling, and processing a number of appliances sufficient to obtain a given quantity of scrap steel will normally be greater than the effort required to obtain the same quantity of scrap from obsolete automobilies. An additional problem thought to affect the recycling of household appliances is that many of the larger ones, e.g., refrigerators, freezers, and ranges, bear a procelain coating known in the trade as "frit". A recent study by Whirlpool and Inland steel concluded that these porcelain coatings do not constitute a significant barrier in recycling appliances.[5]

Of all major final steel products, steel cans provide perhaps the least accessible source of scrap. A single can contains only an insignificant quantity of steel. Discarded either in landfills where they are mixed in with other types of solid waste or scattered throughout the environment as litter, old cans are quite expensive to assemble into any significant quantity of steel. Other drawbacks in recovering steel scrap from steel cans relate to aspects of product design. While some cans are presently being made from tin free steel, most still contain some tin. Given existing technology and the prices of tin and scrap steel it is not economical to remove this tin, and the desirability of scrap obtained from these cans is greatly reduced. Also steel cans with aluminum tops have presented problems due to the expense involved in separating the two metallic components.

B. Scrap Grades

At the final point in the secondary materials flow cycle, where iron and steel scrap is purchased and consumed by steel mills and iron foundries, it is classified according to grade. This classification scheme is quite extensive and can be extremely confusing. All told the Institute of Scrap Iron and Steel (ISIS) lists 72 grades of processed ferrous scrap in addition to a number of railroad scrap grades and alloy scrap grades.[6] It should be pointed out,however,that a few grades account for about 80 percent of all the processed scrap which is traded. The purpose of this classification scheme is to provide a uniform set of product specifications for processed scrap which is sold by dealers to steel mills. This purpose is not fully achieved, however. There are significant regional differences, such that processed scrap which is sold in one city as a particular grade may be identical to scrap sold in another city as a different grade.

The Bureau of Mines, which reports quantities of scrap shipped to mills as well as quantities of scrap consumed at mills, has adopted this system of classification.[7] Only the most important grades are reported individually, the less important ones being lumped together under headings such as Other Scrap, Other Carbon Steel Scrap, or Other Alloy Scrap. In the Bureau of Mines reports all scrap consumed including home scrap. is classified by grade. In the case of home scrap this is something of an arbitrary practice. Home scrap is not prepared by scrap dealers to conform with the ISIS classifications for the reason that it never leaves the steel mill in the first place. Assigning a given quantity of home scrap to one grade or another reflects a judgement made at the steel mill merely for the purpose of conforming to Bureau of Mines reporting requirements. So little importance is attached to such judgements that there is every reason to suspect that they are made in a rather hap-hazard fashion.

Grade classifications are based upon both the source of the scrap material and the manner in which it is prepared. Typically specifications for individual grades make mention of the source of the scrap material, size of individual pieces of scrap, the compactness or density of bundles of scrap, the presence or absence of dirt or other physical contaminants; and the presence or absence of traces of non-ferrous metals. The most preferred grades call for materials from known prompt sources that are either cut into regular sized pieces or compacted into small dense bundles, free from both physical and chemical contamination.

Several of these points can be illustrated by looking at just a few of the important grades of scrap -#1 Heavy Melting, #2 Heavy Melting, #1 Bundles, #2 Bundles, and Shredded. Together these grades account for more than 50 percent of total purchased scrap (i.e. all scrap other than home scrap). Both #1 Heavy Melting and #1 Bundles are high quality grades which must consist of scrap materials that are free from contaminants such as paint, traces of other metals and dirt. In general this implies that they are made up of prompt materials. For #1 Heavy Melting individual pieces must be no larger than 60 X 24 inches in order to insure that they can be easily charged into steel furnaces. The #1 Bundles, like all other bundled or baled scrap products, are made from compressing scrap materials into compact cubes using large hydraulic rams. The specifications for # 1 Bundles require that they be small enough to fit into the charging box of a steel furnace, and have a density of at least 75 lbs. per cubic foot.

The #2 products may contain materials that are not suitable in either #1 Heavy Melting or #1 Bundles, because of physical contamination or uncertain origins. Large quantities of obsolete materials are found in both #2 Bundles and #2 Heavy Melting. The #2 Bundles are usually made by compacting automobiles hulks which have been stripped of their more valuable parts.

Shredded scrap is produced by a hammer mill or shredder which takes entire automobile hulks and grinds them up into fist-sized bits of metal. As we shall see later on, this process converts automobiles to a processed scrap product which is superior in quality to #2 Bundles. Since its introduction in the middle 1960's it has been rapidly displacing the baling process as the primary technique for converting old automobiles to usable scrap.

C. Supply

In the preceding section we described various flows of iron and steel materials between the point at which they become available as scrap and the points at which they are re-absorbed into primary production processes. In some cases these flows involve substantially more than merely transporting and re-using discarded materials. Rather, raw scrap materials are collected and essentially manufactured into processed scrap products, which only then are suitable for use as inputs in the primary iron and steel industries. In this section we briefly describe the organization and the operations of the industry that transform raw scrap into final scrap products.

Firms which collect raw scrap and transform it into final scrap products are called processors or dealers. There are about 1,500 such firms operating approximately 2,000 facilities throughout the United States. Some of these firms make their own sales of processed scrap directly to user mills. Most deal indirectly through scrap brokers who arrange sales to user mills. Most scrap dealers are relatively small, family owned businesses, though there are a few large publicly held firms in the industry. The estimates in Table 8-1 made by the Battelle Institute give some sense of the size distribution of firms in the industry.

Scrap dealers are heavily concentrated in certain geographical areas. Particularly large numbers of scrap dealers are found in Pennsylvania, Ohio, New York, Illinois, Michigan, Indiana, California, and Texas. This would be expected because the costs of transporting raw scrap to dealers and the costs of transporting processed scrap to users are relatively high. Not only are large quantities of scrap generated in

Table 8-1. FIRM SIZE DISTRIBUTION

Annual volume	Percent of total firms
greater than 500,000 tons	0.5
300,000 - 500,000	1.0
100,000 - 300,000	1.5
60,000 - 100,000	3.5
30,000 - 60,000	7.0
less than 30,000	86.5

Source: Regan and McCleer, p. 180

the densely populated and heavily industrialized regions of these states, but also large numbers of steel mills are located in these regions. Furthermore, large quantities of scrap are exported from some of these states.

Scrap dealers' operations can be roughly divided into four categories: collection, separation, upgrading, and shipping. At one time all of these operations were relatively labor intensive. However, over the last twenty-five years, and especially in the last 10 years, major changes have occurred in the industry. Specialized pieces of capital equipment have been developed which play significant roles at most stages of scrap processing. We shall describe some of the more important kinds of capital equipment and some recently developed processing techniques in order to provide some insight into the workings of a modern scrap processing facility.

At the collection stage both truck and rail transportation have always been very important. An important innovation has been the portable automobile hulk flattener which was introduced in the mid-1960's. This piece of equipment can be moved from one place to another fairly easily. It is used to flatten entire automobile hulks prior to their shipment to scrap processors. Once flattened, up to forty hulks can be transported on a single tractor trailer, whereas only six unflattened hulks can be hauled on the same tractor trailer.

Once raw scrap is collected and delivered to dealers' yards the tasks of separation and upgrading are undertaken. The distinction between these tasks is not always perfectly clear. Often they are accomplished simultaneously and may be more properly thought of as a single task. Those operations in which heterogeneous collections of materials are sifted through and the ferrous materials segregated out, or where ferrous components are detached from pieces of equipment, can be considered part of the separation stage. Operations in which large pieces of raw scrap are reduced to manageable-sized pieces of a more homogeneous nature, or in which physical or chemical contaminants are removed, can be considered part of the upgrading stage. In some instances separation precedes upgrading while in other instances the order of these processes is reversed.

Many separation processes, especially those which precede upgrading processes, are still hand operations; Non-ferrous parts are sometimes removed by hand from automobile hulks prior to upgrading. Mixed batches of raw scrap materials, both prompt and obsolete, are often sorted through by hand. Separation processes which are undertaken after some upgrading has occurred (e.g., after an automobile has been shredded into small pieces) often make use of recently designed types of capital equipment. Magnetic separators are used to separate ferrous from non-ferrous metals, and air knives are used to separate ferrous material from non-metallic debris.

Traditionally,upgrading operations have included burning to remove organic contaminants; breaking or cutting of large, irregularly shaped pieces of scrap into smaller uniform pieces with hand operated equipment; and compacting of scrap materials into bales or bundles with the use of hydraulic rams. Advances in upgrading equipment include the guillotine shear introduced in the late 1950's and more recently the scrap shredder or hammer mill. The guillotine shear uses a hydraulically powered blade to cut pieces of steel of up to 6 inches in diameter. It is a highly versatile piece of equipment which is useful for processing a wide variety of different raw scrap materials. This versatility makes it especially valuable in small scale scrap processing facilities.

By far the most significant development in the iron and steel scrap processing industry in the past several years is the scrap shredder or hammer mill. The first of these machines began operation in 1961.

It was not until the late 1960's that shredders became at all widespread. Since that time growth of shredder capacity has been very rapid.

Objects like appliances and automobile hulks are fed into the shredder, and then, as the name implies, are shredded into fist-sized bits of metal. As compared with either of the two pre-existing methods for processing these objects, the shredder represents a substantial improvement. Formerly automobile hulks were upgraded into processed scrap either by cutting the hulk into many pieces with relatively simple tools, the most advanced of which was the guillotine shears, or by compressing the hulk into a compact bundle with large hydraulic rams (a baler).

The first of these methods, shearing, produces a high quality scrap product since once cut up the ferrous components of the auto can be completely segregated from other metallic and non-metallic parts. Shredding is capable of producing a scrap product of equal or comparable quality,since once it is shredded the ferrous component of an auto hulk can be segregated from other metals (with magnetic separators) and from non-metallic materials (with air knives). The advantage of the shredder is that it is a less time consuming and less labor intensive process than shearing processes. Where there are large numbers of autos to be processed into scrap, shredding can produce the same high quality product at a significantly lower per-unit cost.

As compared with the second method, the baling process, the shredder enjoys a quality advantage rather than a cost advantage. Both methods are highly capital intensive and the circumstances in which one method achieves lower per-unit costs than the other are not perfectly clear. However once automobile hulks are compressed, non-ferrous metals and other contaminants can no longer be separated from the ferrous materials. Therefore #2 Bundles, the scrap product made from compressing auto hulks, is judged inferior to shredded scrap.

D. Demand

(1) Introduction

Scrap in its various grades is used as an input in the production of raw steel, cast steel and cast iron. It competes in this capacity with other iron bearing inputs which are derived from virgin ores. These other inputs are often placed in two broad categories: pig iron or hot metal, iron which has been refined (reduced) in a blast furnace as the final stage in its upgrading; and pre-reduced ores, presently of minor significance, which are upgraded by means other than a blast furnace. Also of particular relevance to this report is the fact that a large amount of coke, a derivative of coal, is required in the blast furnace process which transforms iron ore into pig iron. Some limestone is also consumed in this process. In effect scrap competes with three complementary virgin material inputs. All three of these materials happen to receive favorable tax treatments which should be taken into account in computing the price advantage conferred upon virgin materials by the tax code.

The amount of scrap which is consumed should depend upon its price, the price of virgin inputs with which it competes, the level of steel production, the nature of the steel producing capital stock in place at a particular time, and the nature of existing steel producing technology. In the long run capital stock is variable and is itself determined in part by the relative availabilities of scrap and virgin inputs. For instance, if a change in tax policy raised the price of virgin inputs,we might expect to see, after a time, a relative increase in the proportion of furnaces capable of accommodating large amounts of scrap. Also technology changes over time and the particular course which this development follows will depend upon the availability of scrap and the availability of iron from virgin sources.

We shall begin with a discussion of steel production processes. This should allow US to identify the limits imposed by existing capital stock and existing technology, beyond which no further substitution of scrap for virgin inputs can take place in the short run. These limits mark the point at which short-run demand for scrap becomes entirely unresponsive to relative scrap prices, and at which tax policies which further inflate virgin prices should cease to have short run effects on the rate of recycling. Long run effects may still be felt however, since these depend upon how quickly the limits imposed by technology might themselves be expanded either by alterations in furnace capacity or by technological change.

Examination of steel production techniques should also give us a rough notion of how easily scrap can be substituted for virgin inputs within the limits of existing technological feasibility. This in turn gives us a rough idea of the amount that the quantity of scrap demanded (short-run) might increase for a given change of relative input prices in favor of scrap. Later on we will refine the estimates with the help of econometric techniques. At this point,however,it is important to get as full an understanding of iron and steel manufacturing as we can; this will aid in constructing reasonable models and properly interpreting the results of our own models as well as the models of others. It will also allow us to recognize the limits of these models so that undue reliance is not placed upon so-called "hard" or "quantitative" estimates of demand for scrap.

(2) Steel-making Processes

Steel is produced by melting iron in the form of pig iron, scrap or pre-reduced ore and driving off through an oxidation process various impurities such as carbon, silicon, manganese, phosphorous and sulfur. At the same time the molten iron may be blended or alloyed with other elements such as tin, nickel, copper, chromium, and molybdenum, which import qualities to the steel that are valuable in particular end uses.

For instance, copper improves the resistance.of steel to atmospheric corrosion and increases strength.

The production process is generally carried out in one of three types of furnace: open-hearth, basic oxygen, or electric. These furnaces differ significantly in their abilities to use scrap as an input. Thus, in the short run, one would expect that existing capacities of different furnace types could help explain the demand for scrap. In the long run, as new furnaces are built to replace those that wear out, one should expect the choice of furnace type to be affected, in part at least, by the relative prices of scrap and virgin inputs.

(3) The Open-Hearth Furnace

The open-hearth furnace is very flexible in that it is technologically capable of accepting a charge of inputs composed entirely of scrap or one composed entirely of pig iron. Over the last several years open-hearth furnaces have operated on average with charges of iron inputs containing 40 percent to 45 percent scrap.[8] In open hearth production scrap and virgin inputs are not perfect substitutes distinguishable solely on the basis of relative price. Furnaces may operate more efficiently (in a technological sense) with certain balances of scrap and virgin inputs . For instance, in a "hot metal process" where scrap and molten metal are charged into the furnace, energy requirements are reduced and melt time is shortened when a higher proportion of the charge comes directly from the blast furnace in the form of hot metal. On the other hand when cold pig iron and scrap are used in a "cold metal process," energy requirements are increased as the proportion of pig is increased because of the higher amounts of carbon and phosphorous which must be driven off from the pig. Also high quantities of the metallic impurities found in scrap may deteriorate furnace linings.

While the technicalities of the input substitution process in the open-hearth furnace may affect the short run demand for scrap, over the long run we need not be so concerned with substitution possibilities. The share of steel output attributable to the open-hearth has been declining over the last ten years. This trend is expected to continue since no new open-hearth capacity is presently being constructed. It is predicted that by 1985, only 7 percent of steel output will be produced by the open-hearth process.[1] The shift away from open-hearth production has occurred because newer processes are considerably more efficient. For instance, the basic oxygen furnace produces a batch of steel in 45 minutes while the same operation takes 10 hours in an open-hearth furnace. While declining scrap prices might make the flexible open-hearth furnace somewhat more competitive with the newer technologies (that are less receptive to scrap inputs), it is unlikely that any change in input prices will reverse or even seriously retard the trend away from open-hearth production. Nor do there appear to be any potential technological improvements in the open-hearth process which might be spurred on by a drop in the relative price of scrap inputs.

(4) The Basic Oxygen Furnace

Introduced in this country in the late 1950's, the basic oxygen furnace is considerably more efficient than the open-hearth. As open-hearth furnaces have worn out over the last 15 years they have been replaced with BOF's. This trend is expected to continue in the foreseeable future.

The BOF is more limited than the open-hearth in its ability to accept scrap as an input. Presently existing technology is such that the charge of iron normally consists of no more than 30 percent scrap.[9] Whereas in the open-hearth furnace an external source of heat is used to melt the charge and induce the oxidizing reaction which drives off impurities, no external heat is applied in the BOF. Molten metal is fed directly from the blast furnace into the BOF which already contains a certain amount of cold metal. Oxygen is then injected into the molten metal at high speeds in order to stimulate the oxidation process. The reaction must proceed quite rapidly because the heat given off by the hot metal must be sufficient to melt the scrap in a very short period of time. An upper limit is thus established upon the portion of the charge which can consist of cold scrap. This limit is determined by the energy requirements for melting cold metal and the capacity of the molten metal to supply this energy. In general, molten metal is capable of melting a quantity of cold metal no more than half its own weight.

There are a number of relatively undeveloped technological procedures which permit the use of more scrap in the BOF. These are of particular interest here since the incentives to develop them might increase in response to a tax-induced decrease in the relative price of scrap. The most promising technique seems to be the pre-heating of scrap. This is an attempt to reduce the energy requirements for melting scrap which has been charged into the BOF. Rather than being added to the BOF as cold metal, scrap is heated with an external source before going into the furnace. It has already been shown to be technologically feasible for BOF's to consume up to 50 percent scrap by pre-heating the cold metal for 20 minutes.

A second possibility for increasing scrap consumption in BOF's is the use of internal fuels. Scrap and a solid fuel such as calcium carbide are charged directly into the BOF and the fuel is ignited, heating the scrap. Molten metal from the blast furnace is then added and the BOF reaction proceeds as usual except that smaller quantities of hot metal are necessary to finish melting the already heated-scrap.

Other innovations include increasing the temperature of the hot metal which is added to the BOF, thereby increasing the energy available to melt the cold metal portion of the charge; and pre-heating the oxygen which is blown in during the melting cycle.

These various attempts to increase scrap usage in the BOF are mentioned to illustrate, that at present it is technologically feasible to use more than 30 percent scrap in the BOF. Also in a number of cases where virgin inputs were in relatively short supply, it has become economically efficient to use charges which are more than 30 percent scrap.

No rigorous economic analysis exists which is capable of showing what input prices (e.g., for scrap, pig iron, fuels for.pre-heating) are necessary before presently known pre-heating technologies become economically efficient. Nor would this tell the whole story since technology in this area is not static. Decreasing relative prices for scrap. would undoubtedly stimulate efforts to find cheaper ways to use more scrap in the BOF. How successful these efforts might be is still a matter of some speculation.

(5) The Electric Furnace

In the electric furnace, inputs, usually consisting of 100 percent scrap, are placed beneath graphite electrodes, which pass a current through the cold metal. The electric resistance provided by the metal supplies the heat necessary to accomplish the melting process. Oxygen may be blown into the furnace to aid in the removal of impurities.

While there is no room for substitution of scrap for virgin inputs in electric furnace steel-making, it is still the case that declining relative prices for scrap could lead to increased scrap consumption within this sector of the industry. Electric furnace capacity is much more flexible than BOF or open-hearth capacity. Small facilities (mini-mills) can be built with a relatively small commitment of capital and can be located close to supplies of scrap. Thus it is likely that electric-furnace capacity, would expand in response to declining relative prices for scrap. Also there are a number of potential technological changes which might improve the efficiency of electric furnace steel-making. A decline in the relative price of scrap might hurry the development and introduction of these changes, thus making scrap even more attractive as an input to steel-making.

(6) Output Specifications - The Residual Contamination Problem

A second type of technological factor affecting the demand for scrap as an input to steel production relates to output specifications. As we described above the production of steel from iron involves both the removal of impurities and the addition of alloys. The impurities mentioned (e.g., carbon, phosphorous, sulfur, silicon) are all removed from the iron in the steel furnace. However, in addition to these there are a number of other elements (such as copper and nickel) which cannot be removed in the normal course of steel-making operations. The only way to limit the amounts of these "tramp" elements which end up in the final batch of steel is to choose iron inputs which are themselves suitably low in "tramp" content.

The problem of dealing with "tramp" elements is somewhat more complicated than what we have posed thus far. While we have been implicitly assuming that all steel output is of uniform chemical composition there are actually a number of grades of steel. The peculiar chemical composition of each grade determines the physical characteristics which make it suitable for particular end uses. Thus some grades may be higher in tramp content than others. The situation is not that some grades are simply more tolerant to tramp contamination, but rather that some grades actually require minimum quantities of these elements in order to meet specifications. Elements which are classsified as tramps in the production of some grades are the very same as the alloy elements which are blended in to impart desirable physical characteristics to other grades.

The technical constraint posed by output specifications affects the desirability of scrap as an input in two ways. First of all scrap tends to be relatively high in tramp content. One reason for this is that some scrap is derived from alloy steel. A second reason is that in the processing of scrap it is very difficult to remove all traces of other metal which may have been attached to the obsolete product from which the scrap was derived.

Since tramps are not easily removed in the steel furnace it may be necessary to dilute scrap with large quantities of virgin iron in order to bring the batch of steel up to specifications. Producers can only substitute scrap for iron in response to a shift in relative prices so long as they have not run up against the maximum limits on tramp content.

A second problem with scrap is the large variance in tramp content among shipments of the same classification. Steel producers have no guarantee that a particular batch of, say, #2 Heavy Melting scrap does not contain considerably more than the average amount of copper for this category. It is very costly to accurately analyze the tramp content of a bundle of scrap - until after it has been melted down. Hypothetically, this could cause whole batches of steel to be ruined since it may not be possible to correct for errors in judgment once the furnace cycle has begun. This is an especially severe problem with the BOF, where the entire reaction must proceed extremely rapidly in order to maintain the necessary energy balance. Furnace operators who wish to avoid costly mistakes must seek a margin of safety by consuming only small amounts of scrap inputs of uncertain quality and diluting these with virgin inputs of known composition.

The characteristics of contamination and variable quality suggest that only moderate amounts of lower grades of obsolete scrap might be consumed, and that the quantity consumed might be unresponsive to downward movements in scrap prices around present equilibrium price levels. AS long as this unresponsiveness prevails, tax policies which alter relative prices of scrap to virgin inputs can have little impact upon the rate of recycling. An upgrading of the quality of scrap might improve this situation in two ways. First, even with the existing tax policy, the level of scrap consumption might rise as the scrap became more acceptable as an input; that is, demand for higher quality scrap should be greater than for low quality scrap. Second, changes in relative prices induced by tax policies, might have a further pronounced effect upon the amount of scrap consumed; that is demand for better quality scrap might be more elastic than demand for low quality scrap.

The introduction of the automobile shredder is an example of a technological change which in effect transforms auto hulks into a different product for which demand is higher and probably more elastic. The shredder opens up a source of high quality scrap in the following way. The steel going into automobile bodies must be flexible and capable of. being rolled into thin sheets. Such physical characteristics are "achievable only with steel that has an extremely low alloy content. Compared with scrap from obsolete industrial equipment, made of lower grade steel, auto scrap has always been potentially superior. In spite of this the grade of scrap previously derived from obsolete automobiles (#2 Bundles) was judged inferior to that derived from old industrial equipment, the reasons for this being that scrap processing methods such as baling create a product in which the other metallic parts in the auto hulk become mixed in with the steel. The amount of steel in a single auto hulk does not justify the removal by hand of all other metal parts before the car is processed. Usually a car is stripped only of those parts which are resalble or which are particularly. easy to remove. Auto hulks containing other metals are simply compressed into compact bundles which can be easily transported and fed into steel furnaces. Once these bundles are compressed it becomes impossible to physically separate the steel from tramp metals such as copper. Consequently the substance derived when these bundles are melted down in the steel furnace contains high percentages of tramp elements.

Shredding on the other hand breaks an auto hulk into fist-sized pieces. These bits can be separated magnetically so as to reduce tramp contamination in the scrap product. Autos which are shredded achieve a quality and command a price comparable to that of #1 Heavy Melting, a better grade of scrap.

(7) Iron and Steel Foundries

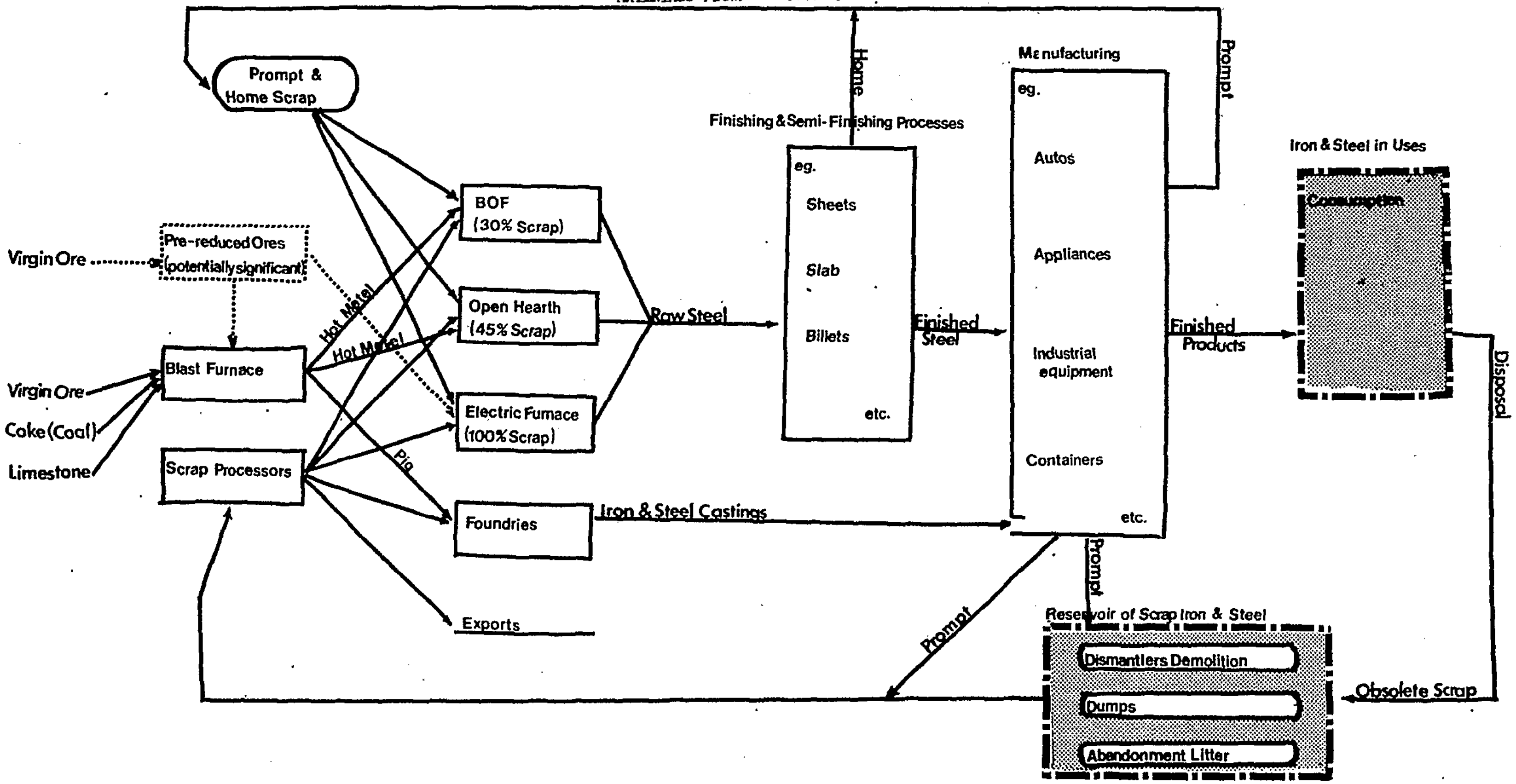
Iron and steel foundries use scrap and pig iron to produce a wide variety of ferrous castings. These products fall into three general categories: gray and ductile iron castings, malleable iron castings and steel castings. Also there are three technologies in use which account for almost all foundry output. The cupola furnace is responsible for about 90 percent of cast iron production. The electric furnace provides the remainder of cast iron output as well as about 70 percent of cast steel output. The other 30 percent of cast steel production comes from open-hearth.

The casting sector accounts for approximately 20 percent of annual domestic consumption of scrap iron and steel. Unlike raw steel production there are no strict technological limits upon the amount of scrap which can be used. All three processes are capable of receiving charges that consist of 100 percent scrap. While these facts suggest that foundry consumption of scrap might be highly responsive to a drop in its relative price,no significant increase in scrap consumption is likely to occur in this sector. This is because scrap inputs are already such a large percentage of total iron inputs that little room is left for further substitution of scrap for virgin. Electric furnaces already use input charges that are close to 100 percent scrap. Cupola furnaces can use shredded, but not #2 Bundles,in charges that average 85 percent scrap. Open-hearth furnaces operate with inputs that are 90 percent scrap.

Nonetheless, possibilities for substitution do exist. In the short run cupola furances could accept even higher charges of scrap than they

Figure 8-1

MATERIALS FLOWS IN THE STEEL INDUSTRY



do now. There has been a clear trend towards increased scrap consumption (Regan, McCleer).

II. ECONOMETRIC MODEL

A. Introduction

For this report it is most important to obtain estimates of how the quantity of scrap supplied responds to changes in its own price, and how the quantity demanded responds to changes in the cost of obtaining pig iron, the principal virgin substitute for iron and steel scrap. Also of considerable interest is the relationship between the quantity of scrap demanded and its own price. Econometric techniques were used to estimate supply and demand equations for iron and steel scrap to provide quantitative measures of these parameters.

In this study we are most concerned with that 'portion of iron and steel scrap which is actually retrieved from the environment, rather than that which is automatically recovered as part of the ordinary steel production cycle. The portion which we are interested in includes all obsolete scrap. It also includes some small but unknown portion of prompt scrap which gets released into the environment when scrap prices are low, instead of being recycled immediately or held by scrap dealers or metal fabricators in anticipation of higher prices.

Separating the flow of automatically recovered pig iron and steel scrap from the remaining portion represents a major problem encountered in the course of this study. Ideally, one would like to have two separate data series in order to estimate supply equations for each category. Unfortunately, this procedure could not be followed. In part, this is because of the poor quality of the data. Statistics which would permit separation of all prompt from all obsolete scrap are not even kept. In addition, there are conceptual difficulties in drawing a line between high quality secondary materials which are returned to steel mills through what is essentially a series of exchanges, and secondary materials which have actually been "produced" from raw scrap.

Two strategies were employed to meet these difficulties so as to disentangle the impact of prices upon quantity of scrap supplied from the "reservoir" of discarded iron and steel from the impact of prices upon the rate at which high quality prompt flows back to steel mills. The first of these approaches involved using what seemed to be the most consistent reliable series of quantity data, that for total purchased scrap, even though this category is overly broad. Total purchased scrap includes all obsolete scrap as well as all prompt scrap. A more desirable series would exclude most of the prompt scrap, since this falls into the category of high quality materials. that would be returned to steel mills or iron foundries in a short time under any reasonably anticipated set of circumstances. The supply equation for this broad category was specified to include non-price variables which affect the amount of automatically recovered material which is received at steel mills in each period, thus accounting for the prompt portion included in the total purchased scrap series.

The other strategy for estimating the price responsiveness of iron and steel scrap was to work directly with more highly disaggregated data. For this report the quantity series for individual grades of scrap were used (see Table 8-2). The advantage of this method is that the non-price factors which influence the rate at which easily accessible prompt scrap flows back into the steel production sector could be ignored. A disadvantage is that it is very difficult to obtain consistent data series which report the same quantity, spanning any appreciable length of time.

The modeling efforts proceed as follows. In Section B we state the hypothetical supply and demand relationships for iron and steel scrap, listing the factors to be included in each relation. These relationships are then elaborated in Section C, "Variables," where the theoretical basis for each is developed. In addition, there is some discussion of the appropriate measures for each variable employed in the supply and demand relationships, and of the data which is available for testing each hypothesis in the context of a supply-demand model. Finally in Section D this discussion is drawn together as we present the models which were actually tested.

B. Hypotheses

It was postulated that the quantity of scrap supplied to domestic consumers during any one month depends upon:

1. Price of processed scrap.
2. Activity in the scrap export market.
3. State of technology and the quality of capital stock in the scrap industry.
4. The availability and accessibility of the raw scrap inputs which scrap dealers collect and prepare for sale to the steel industry.

It was postulated that the quantity of scrap demanded by domestic consumers depends upon:

1. Price of processed scrap.
2. The level of activity in the steel industry, the sector which consumes scrap.
3. The price to steel manufacturers of obtaining pig iron, the virgin input with which scrap competes in steelmaking.
4. The composition of the steel industry's capital stock - different kinds of steel furnaces vary in their abilities to accept scrap inputs - and the state of technology in the steel industry.

Others have developed econometric models which encompass the scrap steel industry In particular, we note the work of Adams[4] (a primitive model), Higgins,[10] Johnson,[11] and Russell and Vaughan[12] (a process or engineering approach).

C. Variables

(1) Quantity of Scrap

AS discussed previously, one may identify two loosely defined categories of iron and steel scrap: 1) materials which are automatically recovered as part of the steel production and fabrication process, and 2) materials which are retrieved or diverted from the environment only with the expenditure of some significant amount of effort. Home scrap falls into the first category. It is 100 percent recycled, and would continue to be recovered regardless of the price of scrap. Obsolete scrap falls into the second category. It is retrieved from the environment only when scrap prices are high enough to defray the cost of this activity. Conceivably, the price of scrap could drop to a level where no obsolete scrap was supplied at all. At this hypothetical low price it would be unprofitable for private individuals to collect and process even the most accessible obsolete scrap.

Prompt scrap is less easily dealt with in terms of these categories. There is some indication that a portion of prompt material, perhaps ten percent, is not recovered other than during periods of extremely high prices. Clearly, this portion falls into the second category. On the other hand, the highest quality prompt scrap is certainly in the first category. It is presently collected at fabricating plants and returned to steel mills as a routine part of the production cycle. This is a practice which should continue, barring only the most major change in steel-making technology or input costs. It is impossible to say exactly how much prompt material fits into this category, but for the purposes of this study it is sufficient to recognize that not all prompt scrap is automatically recovered.

This investigation is concerned with the supply and demand of scrap which falls into the second category. This includes all obsolete scrap and that portion of prompt material which is recovered only during periods when scrap prices are high enough to compensate individuals or firms for the efforts required to divert or remove such material from the environment.

The first problem which one encounters in trying to estimate these relationships econometrically is obtaining an appropriate data series for quantity of scrap. Ideally, one would want to work with quantity figures which did not include any high quality automatically recovered material, but which did include all obsolete and low quality prompt material. Such a data series is difficult to construct for two reasons. First some automatically recycled scrap follows the same materials flow paths as obsolete scrap, and thus is included in the figures reported for this latter category. Second, even the series which records the movement of materials of both types through these flow paths has not been kept with any consistency. Both of these points will be developed below.

Monthly statistics on iron and steel scrap are reported by the Bureau of Mines in the publication Monthly Mineral Industry Surveys. The first point in the secondary materials flow at which statistics are reported is where scrap is received by steel mills and iron and steel foundries: scrap receipts. After this, statistics are reported for quantities of scrap consumed in primary production processes. In general, data at this later stage are less useful because these figures include varying amounts of home scrap which, never having left the mill, were not included with receipts.

There are no published figures on materials flows into scrap dealers' yards, nor on inventories held by scrap dealers. In addition, there is not a continuous data series on quantities of scrap which bypass dealers altogether and are shipped directly from fabricators' plants back to steel mills. Were any of these data available, they would be quite valuable for purposes of identifying by source (e.g. obsolete, automatically recycled prompt, or marginal prompt) scrap which is supplied to the primary steel industry. Also these data would be valuable for purposes of distinguishing fluctuations in the quantity of scrap supplied which are introduced by speculative behavior on the part of scrap dealers, from fluctuations which reflect changes in the level of effort expended in collecting and processing scrap.

Reported receipts of scrap at steel mills are broken down by scrap grade, the industry's classification of scrap dealers' outputs. This categorization is based upon the quality which scrap achieves after it has been processed by dealers. Because quality at this point is a function of both the source of the material as well as the amount of processing it has received, it is not possible to divide scrap grades into those which contain only automatically recycled material and those which contain only obsolete and low quality prompt material. Nor is it possible to separate all prompt scrap from all obsolete scrap. Most grades include at least some material from a number of different sources.

While industry classifications of scrap grades do not permit a perfect breakdown between scrap from high quality sources and scrap from low quality sources, a fairly close approximation should be possible. There are just a few grades which account for a major proportion of all iron and steel scrap. Among these important grades are #2 Heavy Melting, and #2 Bundles which are derived mostly from low quality scrap materials. Recently, shredded scrap has become relatively more important. It is derived exclusively from obsolete scrap materials, mainly junked automobiles. It seemed reasonable to examine these grades either individually or taken together, and to attempt to fit them into a simple supply-demand model. While this model would only be based upon part of the market for iron and steel scrap from low quality sources, it would probably be acceptable as a basis for inferences about the entire market for obsolete and low quality prompt material.

Unfortunately, over the past several years, the Bureau of Mines reporting of these grades has been so inconsistent as to make any time-series analysis extremely difficult. During the years 1963 through 1967 the classification #2 Heavy Melting was dropped from the reporting system altogether. Just prior to 1963 steel mills had been reporting receipts of approximately 200,000 tons per month of #2 Heavy Melting. This quantity accounted for a significant portion of scrap from low quality sources. Starting in January 1963, no figures were reported at all for #2 Heavy. This ommission was due to the fact that survey forms sent out to steel mills and iron and steel foundries no longer included #2 Heavy Melting as a category. Respondents to survey forms decided for themselves where to include these receipts among the other grade classifications still appearing on the forms. Large quantities of this material seem to have been included with #2 Bundles as there is an abrupt jump in the reported figures on #2 Bundles received in January 1963. Unfortunately, this jump accounts for only part of the deleted quantity of #2 Heavy Melting so that it may not be appropriate to interpret 1963 to 1967 figures on #2 Bundles as giving the sum of #2 Bundles and #2 Heavy Melting. Thus, besides a gap in the series on #2 Heavy Melting, stretching from 1963 through 1967, it is also the case that figures on #2 Bundles over this period are not strictly comparable to any series or combination of series reported either before or after those years.

Starting in 1968, reporting of #2 Heavy Melting as a separate category was resumed. However, at the same time another change was made in the reporting system which acts as an obstacle to this Investigation, From 1968 through 1971, the Bureau of Mines stopped reporting statistics on scrap receipts for individual grades and instead gave only consumption figures. The difference between receipts and consumption is accounted for by inventory changes within steel mills and by consumption of home scrap which mills are also asked to classify by grade. Inventory changes are small relative to total receipts. However, an examination of those years when both consumption and receipts are listed showed that home scrap classified as #2 Bundles and #2 Heavy Melting was often as much as one quarter of the total consumption for each of those grades. The home component in these categories also fluctuated rather widely and it was not a constant proportion of consumption in either of these categories.

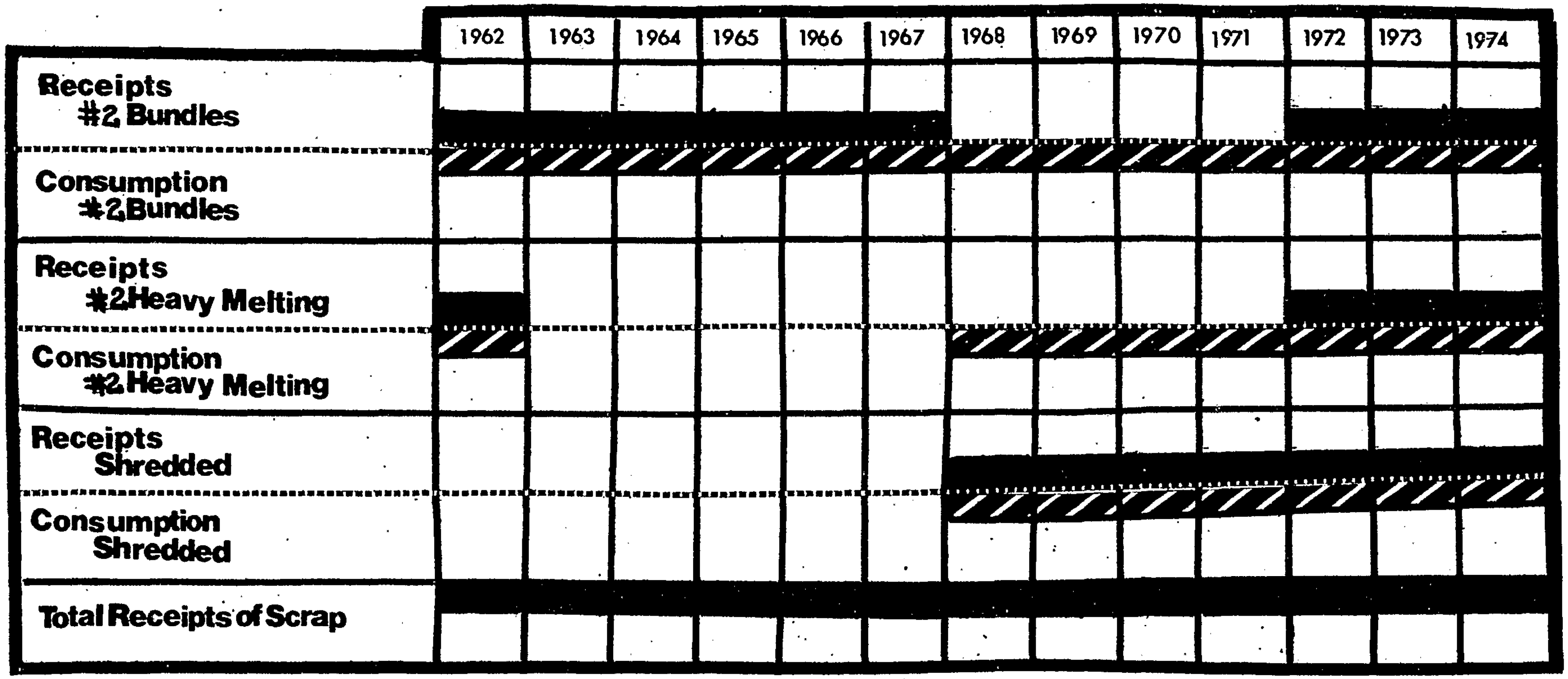
Nor was there any significant relationship between the quantity of home scrap consumed in one period and variables measuring the level of steel production activities which generate home scrap either in the same period or in preceding periods. As a result, it was difficult to use data for periods in which receipts and home scrap were reported separately as a basis for making inferences about the quantity of home scrap included in each month's total consumption statistics for the period 1968-1971.

What is left is a number of fragmented series on receipts of the lower grades of scrap. The years 1963 through 1967 provide a consistent series for receipts of #2 Bundles and after 1972 there are data on receipts for all three grades. Consumption data is available over longer periods, at least for #2 Bundles. However, because of changes in the way scrap materials are classified among different grades in the Bureau of Mines Reporting System, consumption figures prior to 1968 are not comparable with figures after that time. Moreover, consumption statistics are not really appropriate for purposes of this report because they include significant and unpredictable amounts of home scrap.

The poor quality of data for separate grades of scrap forces a heavy reliance upon the series for total scrap receipts, which includes all obsolete and all prompt scrap. This category is obviously broader than desired. However, it is the only data series which has been kept with any consistency over the past several years. Also, while it does include large quantities of automatically recycled prompt scrap, at no point does it include home scrap which is the most easily recovered of all secondary iron and steel material.

TABLE 8-2

DATA AVAILABILITY



(2) Price of Scrap

Prices for various grades of scrap are posted by user mills. The posting of a price indicates a willingness of that user to accept all deliveries meeting grade specifications at that price. Generally, transactions take place between scrap consumers and the scrap brokers who have collected and processed the raw scrap into a more easily transportable and easily usable form. In some cases, however, the dealer is bypassed, and sales are made directly by large scrap generators such as auto manufacturers to scrap consumers. In either case, brokers may intermediate in these transactions.

Scrap prices are quoted daily in a number of cities, and then reported on a monthly basis in various trade publications such as American Metal Markets and Iron Age. These quoted prices often serve as benchmarks from which negotiations between buyers and sellers proceed. They are generally regarded as having been determined by competitive forces since buyers and sellers are relatively numerous, and as giving a close approximation to the prices at which scrap is actually traded on a particular date and at a particular location. This is most certainly true for lower grades of scrap, most of which is bought and sold in transactions calling for delivery within thirty days. Quoted prices may be somewhat less accurate, however, for some higher grades of prompt scrap, especially where the scrap, bypassing dealers, is sold directly to users. Often these sales are part of long term contracts, and, in some cases, the return of such prompt scrap by fabricators is arranged in these contracts as part of the initial sale of steel to these fabricators. In these situations, the reported prices on a given date may diverge somewhat from the previously agreed upon price at which some scrap is actually traded. Nonetheless, the reported scrap prices were regarded as giving a fairly accurate representation of the cost to users of obtaining scrap. The price series used were the Bureau of Labor Statistics Price Indices for Iron and Steel Scrap, deflated by the Wholesale Price Index for all commodities. The composite price index for iron and steel scrap was used when the dependent variable was total receipts of scrap. The scrap index for #2 Bundles was used when the dependent variable was receipts of #2 Bundles.

(3) Technological Change in the Scrap Industry

The data period we are using was one in which there was significant technological change in the scrap iron and steel industry. Improvements were made in existing kinds of equipment such as shearers which are used by smaller scrap processors. Far more important were the introduction and spread of the automobile hulk flattener and the shredder. The portable flattener compresses automobile hulks before they are shipped off to scrap processors. Transportation costs, which are a major component of the cost of supplying processed scrap, are thereby substantially reduced. The shredder was introduced in the middle 1960's and seems to be replacing baling and shearing as the most efficient method of preparing processed scrap from raw scrap inputs, particularly automobile hulks.

Unfortunately no time series data were available which would have allowed us to directly track the adoption of these technological innovations. We were unable to obtain statistics on either shredder capacity or the number of shredders in use at various times. Also we were not able to obtain statistics on the number of flatteners in operation. Lacking this data, a time trend was inserted as a proxy for technological change over this period.

(4) Scrap Exports

Exports were used as an independent variable in the supply equation. They were treated as an exogenously determined quantity that caused a parallel shift in the supply curve. This treatment of exports was based upon the simple hypothesis that a ton of scrap exported reduces by one ton the quantity of scrap which is made available to domestic consumers at a given price. Thus when exports are high, large quantities of scrap are being drained off from domestic markets and the domestic supply curve shifts backward. toward the vertical axis; When export levels are low, the domestic supply curve shifts outward as larger quantities of scrap become available on domestic markets.

Obviously this model oversimplifies things to a considerable extent. Scrap which is exported does not just disappear from the market. Rather it is sold to foreign buyers for a price which in equilibrium tends toward the American price; The quantity sold abroad is determined simultaneously by a total supply equation which includes domestic supply plus exports, a domestic demand equation, and a foreign demand equation. Foreign demand, in turn, is a function of activity in foreign steel industries, the value of the dollar measured against various foreign currencies, as well as U.S. and foreign scrap prices. A more complete model of the U.S. scrap industry would have to take into account these factors and would include at least two separate demand equations, one for domestic demand and one for foreign demand. It might be necessary to break down foreign demand even further among some of the larger scrap importing countries. Because of time and data constraints, the decision was made. to dispense with foreign demand equations. There was no data available to explain historical export patterns for scrap, nor was there information with which to forecast future trends in foreign demand for scrap.

The treatment of exports used in this study assumes that foreign demand is determined independently of domestic prices and moves only in response to factors such as activity in foreign steel industries and fluctuations in foreign exchange rates. To the extent that this assumption is correct, a model which uses quantities supplied to domestic consumers is appropriate for purposes of forecasting the environmental effects of an increase in domestic demand for scrap. If foreign demand is completely inelastic, any increase in the quantity of scrap consumed domestically which might result from a tax induced outward shift in the domestic demand curve must come entirely from scrap which would not otherwise have been recycled. Each additional unit of scrap going to domestic consumers is an additional unit removed from the environment.

On the other hand, if foreign demand is not inelastic, then as domestic demand shifts outwards, the increase in quantity supplied to domestic consumers will be greater than the increase in quantity supplied to all consumers. Only some of the additional scrap going to domestic consumers will come from net additions to the quantity of scrap recycled.

Since an additional unit of scrap to domestic consumers is not an additional unit removed from the landscape, the environmental effect of a tax policy change would be less pronounced than the model used might suggest.

(5) Availability of Raw Scrap

The supply of processed iron and steel scrap is affected by the availability of obsolete products which contain iron and steel, and by the availability of ferrous by-products from metal fabricating processes.

As a proxy for the availability of obsolete products we used a four month distributed lag on iron and steel scrap prices. The rationale for this approach was developed in Chapter 7. Briefly, we postulated that if scrap prices were high in recently past periods intensive collection efforts would have been undertaken, leaving the reservoir of obsolete iron and steel products relatively depleted. Conversely, low scrap prices would have stimulated less intensive collection efforts, leaving larger quantities of accessible iron and steel products available for collection in the present period.

The availability of ferrous by-products from metal fabricating processes, or raw prompt scrap, was represented by a composite index based upon levels of activity in a number of prompt generating sectors. Production levels in these sectors should be directly related to the quantity of prompt scrap which is generated each month. In turn, the quantity generated during one month should have some effect upon the scrap supply curve in succeeding months. The index used was constructed as a weighted average of the Federal Reserve Indices for automobile production, production of industrial equipment, production of appliances, and production of transportation equipment. Automobile production received a weight of 1/2 and the other three indices received weights of 1/6. This weighting scheme was suggested by estimates reported in various issues of the ISIS Yearbook of the quantities of prompt scrap generated in various sectors. A one month lag was used.

(6) Activity in Scrap Consuming Sectors

The demand for scrap in any period is related to the levels of activity in those production processes that consume scrap as an input. These processes include: 1) the production of raw molten steel (which is either hardened into ingots or formed immediately into semi-finished shapes in continuous casting operations), 2) the production of steel castings, and 3) the production of iron castings. Also small amounts of scrap are sometimes charged directly into blast furnaces which reduce iron from its ore.

Production figures which encompassed steel and steel castings were used to represent a composite activity level for all scrap consuming processes. This treatment does not take explicit account of the iron foundry sector. However, it seemed justified, for the sake of convenience, on the grounds that 1) by far the largest quantities of scrap go into the production of raw steel and steel for casting (about 85 percent of total scrap consumption) and 2) activity in the non-integrated foundry sector generally parallels activity in the steel industry.

Data were taken from the American Iron and Steel Institute's series on raw steel production, which covers both raw steel and steel castings.[13]

Further research efforts might attempt to use a more detailed breakdown of demand exerting activities. Demand by the iron foundry sector could be examined separately from demand by steel producers. Also within the steel industry demand for scrap is affected by the mix of steel output being produced. For instance scrap can be used much more easily in the production of alloy steels than in the production of carbon steel.

There has been some increase in alloy steel production as a percentage of total raw steel production over the last 15 years (7.5 percent in 1960 to 10.7 percent in 1973). With other factors remaining constant this should have caused some increase in the demand for scrap. At the same time however,there were changes in the product mix which should have dampened scrap demand: flat rolled products which require the highest quality carbon steel increased as a percentage of finished steel products. Only small amounts of scrap can be used in the production of these high quality carbon steels.

(7) Price of Pig Iron

According to economic theory, the demand for scrap should depend upon the cost of virgin based substitutes; these include pig iron and pre-reduced iron ore pellets. Since pre-reduced ores have not competed on a wide scale in the past they need not be considered any further at this point. Substitution between scrap and pig iron (both as solid "merchant pig" and as molten "hot metal") occurs either through altering the mix of inputs to particular production processes, or through switching among production processes that consume scrap and virgin materials in different fixed proportions.

Unfortunately, it is difficult to obtain a reliable indicator of the real cost of pig iron. There are basically two reasons for this. First, most hot metal is consumed by large integrated firms which supply their own needs. At least 90 percent of the pig iron produced is never traded in the market. Most of this is simply poured directly from a blast furnace into an adjoining steel furnace while it is still in a molten state. There is some question, then, of whether the market price at which the remaining 10 percent of cold "merchant pig" is traded, accurately reflects the real short-run marginal cost to an integrated steel producer of supplying himself with "hot metal". This question persists, even assuming that the market price for pig is competitively determined and is accurately reported.

A second obstacle to obtaining accurate estimates of the real cost of pig iron is caused by the nature of the "merchant pig" market itself. The number of sellers in this market is small enough to arouse the suspicion that it is not a perfectly competitive market. There are about 30 firms operating blast furnaces in the United States (AISI Directory of Iron and Steel Works of the U.S. and Canada). Therefore, it is hard to tell whether,or by how much,prices diverge from those which would prevail under pure competition. What is clear, however, is that list or reported prices are not competitive. List prices change very rarely, and it is generally held that they do not represent the price at which pig iron is actually traded. During periods of blast furnace overcapacity there may be substantial discounting below the list price. During periods of shortage, list prices may be exceeded. In addition, rationing may occur either at the reported price or at prices above this level.

Despite these shortcomings, list prices for pig iron were used in the demand equation for scrap in an effort to measure the cross-elasticity of demand for scrap with respect to virgin materials prices. The series used was the B.L.S. price index for pig iron and ferro-alloys. The main justification that can be offered for this procedure is that of necessity: no series exists for either actual transaction prices or for the internal accounting, prices for pig iron which is not traded on the market.

As an alternative to relying on reported pig iron prices, an attempt was made to construct an index which more accurately reflected the marginal costs to integrated steel producers of obtaining virgin hot metal. Our efforts were based on the assumption that the marginal cost of obtaining pig iron rises as blast furnace output approaches 100 percent of capacity. Proceeding from this assumption we first attempted to obtain figures for blast furnace capacity. Unfortunately the only source for these figures, the AISI Statistical Yearbook, stopped reporting them in 1960. Since 1960, only statistics such as numbers of blast furnaces in and out of blast, new additions to the blast furnace stock and numbers of furnaces permanently shut down have been kept. These were of no help in estimating the trend in furnace capacity, however, because technological advances during the 1960's tended to increase the capacity of even those blast furnaces already in existence.

Finally we made our own estimate of blast furnace capacity. Monthly production statistics for 1959 through 1974 were arrayed, and a number of peak production months were identified. A brief survey of the trade journals for these months turned up statements to the effect that blast furnaces were operating at 100 percent of capacity. A linear trend was then fit through these points and monthly furnace capacity was estimated by interpolating along this line. Some confirmation of the accuracy of this technique was provided by comparing our estimates for years prior to 1961 with figures reported in the AISI yearbook. In all cases estimated capacity came within two percent of reported capacity.

Using our estimates of blast furnace capacity, a capacity utilization series was computed and included in the demand equation as a proxy for the price of pig iron. In addition we experimented with a number of transformations of this index. These transformations were based on the notion that marginal costs are constant up until some level (around 80 percent capacity), and then rise at an increasingly rapid rate as capacity utilization approaches 100 percent.

These proxies had t-ratios below unity in the estimated demand equation and were dropped from further consideration.

(8) Technological Change in Scrap Consuming Sectors

The introduction and spread of the basic oxygen furnace (BOF) over the last fifteen years is frequently cited as a factor which has dampened the demand for scrap. This hypothesis is based on the fact that substitution of scrap for virgin inputs is more tightly constrained in the BOF than in the open-hearth furnace which preceded it as the predominant steel-making technology. While scrap does not substitute perfectly for pig-iron in the open-hearth furnace, it is at least technologically feasible to use a charge of 100 percent scrap. Actual furnace charges have averaged about 55 percent virgin and 45 percent scrap. On the other hand, until recently there has been an assumed upper limit of 30 percent on the proportion of scrap which can be used in a BOF. Presently, some firms are employing techniques such as preheating scrap, which decreases the virgin hot metal requirements of the BOF and allows the 30 percent limitation to be exceeded. However, these practices were not widespread during the period analyzed in this study.

The extent of the changeover from the open-hearth to the BOF between 1962 and 1972 was significant. In 1962 the percentages of raw steel production from the BOF and from the open-hearths were, respectively, 5.6 percent and 84.3 percent. By 1972 the percentage from the BOF had risen to 55.9 percent, and that from the open-hearth had dropped to 26.2 percent.

Tending to counteract any effect that this trend might have had on the demand for scrap was the increase in electric furnace capacity over these years. Small electric furnaces, operated by non-integrated firms, have opened up throughout the country. These furnaces, which use scrap as the only iron bearing input, are especially concentrated near large sources of scrap.

Electric furnace production as a percentage of total raw steel output has expanded from 8.8 percent in 1962 to 17.3 percent in 1972. It is not unlikely that this development was actually a consequence of the adoption of BOF technology by the large integrated mills. As the integrated mills decreased their consumption of purchased scrap, electric furnaces sprang up and took advantage of the temporary excess supply of scrap.

Some effort was made to test the hypothesis that the introduction of the BOF caused the demand curve for scrap to shift backwards. Assuming that growth of BOF capacity was itself independent of scrap prices, the proper way to test the hypothesis would be to include BOF capacity or BOF capacity as a percentage of total capacity as an independent variable in the demand equation. It seems fair to say that the growth of BOF capacity was in fact largely independent of scrap prices. BOF's were brought on line by integrated producers to replace worn out open-hearth furnaces and to expand total capacity. During this period, no new open-hearth furnaces were built. At most scrap prices may have had some effect on the timing decision of when to close down marginal open-hearth furnaces. However, it is unlikely that this significantly influenced the timing of investment decisions in BOF capacity.

Unfortunately, there is no data available on steel furnace capacities. As a proxy for BOF capacity, the percentage of total yearly steel output produced in BOF's was used. Obviously, this is not a perfect proxy. It will be relatively accurate during periods when capacity utilization is high for all furnace types. However during periods of slack demand, when excess capacity exists, it is not necessarily the case that all furnace types operate at the same percentage of capacity. If there are unequal utilization rates among different furnace types, the validity of this proxy is questionable.

There are two reasons for expecting capacity utilization rates to differ among furnace types during periods of slack demand. First, open-hearth furnaces are all older than BOF's. When demand drops off there is probably some tendency for the largest cutbacks in production to come from older, marginally efficient furnaces. Since those all happen to be open-hearth facilities, BOF production as a percentage of total production would overstate BOF capacity as ,a percentage of total capacity when capacity is underutilized.

A second reason why capacity utilization may differ among furnace types is that utilization rates may be affected by the relative prices of scrap and virgin inputs. While it was argued above that decisions to invest in BOF capacity were largely independent of input prices, operating decisions are probably tied more closely to relative input prices. When scrap prices are low, the flexible input capabilities of the open-hearth furnace make it relatively attractive as a production technology. At higher scrap prices the cost advantages enjoyed by the open-hearth associated with its ability to consume larger proportions of scrap become less significant.

Recognizing the limitations of proxies which are based upon actual production rather than furnace capacity, we proceeded to include in our demand equation a variable which reflected the adoption of basic oxygen technology to test whether the trend towards increasing BOF capacity affected the demand for scrap. Data was obtained from various volumes of the AISI Statistical Yearbook. A number of proxies were tried including BOF production as a percentage of total steel production, and open-hearth production as a percentage of total steel production. None of these variables had t-ratios of 1.5 or more and were finally dropped from the demand equation. This result may have been due to the limitations in the data pointed out above. However, it is also consistent with the hypothesis that the concurrent spread of electric furnace capacity tended to mitigate any effect that the introduction of the BOF may have had on the demand for scrap.

D. Models

The preceding discussion can be summarized in terms of.two simple supply-demand models given below in implicit functional form.

Model I

$$Q_s = Q_s \quad (P_{scrap}, Av_1, Ex, T_{scrap}) \tag{14}$$

$$Q_d = Q_d \quad (P_{scrap}, P_{pig}, Q_{steel}, T_{steel}) \tag{15}$$

where, Q_s, Q_d = quantity of scrap purchased by domestic consumers which is derived from obsolete and low quality prompt materials

P_{scrap} = price of scrap

Av_1 = availability measure for unprocessed, uncollected scrap originating from obsolete and low quality prompt sources

Ex = quantity of scrap exports

T_{scrap} = the state of technology in the scrap industry

P_{pig} = the cost of obtaining pig iron

Q_{steel} = the level of activity in scrap consuming sectors

T_{steel} = technological factors in the steel industry which affect the ease with which scrap is used as an input.

Scrap prices and scrap exports are for the particular grades of scrap included in Q_s and Q_d.

Model II

$$Q_s = Q_s \quad (P_{scrap}, Av_1, Av_2, Ex, T_{scrap}) \tag{16}$$

$$Q_d = Q_d \quad (P_{scrap}, P_{pig}, Q_{steel}, T_{steel}) \tag{17}$$

where, Q_s, Q_d = total quantity of scrap purchased by domestic consumers

Av_2 = availability measure for automatically recovered prompt scrap

The price of scrap is a composite for all grades, and Ex is total scrap exports.

The supply equation in Model I is based upon the idea that scrap processors are engaged in production from a resource base which consists of discarded iron and steel materials or raw scrap. Scrap prices determine the level of effort expended in exploiting this resource base. Competition in the scrap industry implies that effort is adjusted to the point at which the marginal cost of retrieving and processing the last unit of scrap is equal to the price obtained for processed scrap.

The quantity of scrap which actually gets supplied thus depends upon both the price of scrap and the amount of raw scrap in the environment which can be collected, processed and sold at a profit for the existing price. Changes in the availability and accessibility of raw scrap over time will cause the quantity which gets supplied at each price to change. Put another way, changes in the characteristics of the resource base will lead to shifts in the supply curve for scrap.

In Model II the quantity variable includes not only materials which are retrieved from the environment, but also materials which are automatically recovered in the course of the steel production cycle. In order to control for changes in Q_S, which represent variations in the flow of automatically recovered material, a second availability measure, Av_2, is included as an independent variable in the supply equation. This availability measure is based upon past activity levels in the metal fabricating sectors which generate high quality automatically recovered prompt scrap.

Since both supply equations are for quantities of scrap going to domestic consumers, both include scrap exports as an independent variable in order to account for shifts in domestic supply curve brought on by changes in export levels. Our hypothesis is that exporting scrap reduces the quantity which will be made available to domestic’consumers at any given price, thereby shifting the supply curve backwards.

Technological changes in the scrap iron and steel industry which have affected the costs of collecting and processing scrap are taken into account as is indicated by the variable T_{scrap}

The two demand equations which are essentially the same are based on the notion that demand for scrap is tied to the production of steel. These equations included the variable Q_{steel} which represents the level of production in the. steel industry. Also included are P_{scrap}, the price of scrap, and P_{pig}, the price of pig iron, which is the competing virgin substitute. It is assumed that the level of steel production is independent of the two input prices. Finally the inclusion of T_{steel} indicates that we have attempted to take account of technological changes in steelmaking which are purported to have affected the demand for scrap.

III. ECONOMETRIC RESULTS

Initially the most elementary functional forms were selected for both supply and demand. Each function was assumed to involve a linear additive relationship between the independent variables and the dependent variable. This specification seemed appropriate as a starting point given that we are working with what is basically a static supply and demand model of price and quantity determination, with several exogenous variables which represent factors that may cause either the supply curve or the demand curve to shift from one period to the next. Modifications of these functional forms were considered where there were facts which suggested that an alternative specification might be more appropriate.

On the supply side there is a single behavioral relationship, that between the price of scrap and the quantity supplied. Holding all other variables constant this relationship traces out the usual supply curve. In Model II, the fact that a large portion of the quantity supplied.is automatically recovered prompt material, suggests that the relationship between price and quantity may be non-linear. In the lower portions of the supply curve where quantities supplied can be assumed to come exclusively from prompt sources, one would expect price to have only a slight effect on the quantity supplied. Since this prompt material would get recycled at any price, the supply curve should rise very steeply in this region. Further out along the supply curve where marginal quantities are drawn from obsolete sources the supply curve may flatten out somewhat. Once scrap prices are high enough to make it economically feasible to recover obsolete scrap from the environment, relatively small price changes might bring large additional quantities of scrap into the market. It seems appropriate to at least allow for this possibility because there are presently large accumulations of scrap in the environment.

In order to allow for this potential non-linearity some equations were estimated using a logarithmic transformation of prices. The results were substantially worse than those obtained with a linear specification. However, such results cannot be taken as a positive refutation of he hypothesis just set forth or as proof that the price quantity relationship is uniformly linear along its entire range. If all of our observations happened to fall into the upper range of the supply curve, above the highly inelastic portion where only prompt scrap was recovered, then a linear specification would provide the best fit. The fact that prices have never dipped so low that no obsolete scrap was getting recovered tends to support the view that the industry has always been operating along this outer portion of the supply curve.

Of the other independent variables in the supply equation, linear specifications are most easily justified for exports and for Av_2, the proxy for availability of prompt scrap. For Av_2 this specification follows from the hypothesis that a change of a given magnitude in the level of productive activities that generate prompt scrap is passed back to steel mills, regardless of the absolute level of these production activities. For exports a linear specification follows from the hypothesis that each unit of scrap exported means one less unit of scrap to be made available to domestic consumers regardless of the absolute level of scrap exports.

The proxy for the availability of raw obsolete scrap, Av_1, presents a more difficult case. The functional form which correctly describes this relationship depends upon how quickly the more accessible sources of obsolete scrap become depleted as scrap prices rise. Unfortunately very little is known about this process. Obviously prices cannot climb indefinitely without some dampening of the depletion effect. There comes a point where all physically available scrap will have run out so that there is nothing left to be depleted. However, it is not clear that we were ever close to this point during the data period. The continuing build up of iron and steel scrap in the environment tends to suggest that we were not. Nor is it clear whether the relationship might not be approximately linear in the lower ranges before the scrap reservoir approaches exhaustion. Some regressions were run using a logarithmic transformation of the availability variable; however, these were inferior to regressions which made direct use of the proxy.

On the demand side there was little information to suggest what form the direct price effect should take. Two specifications were considered; a simple linear relationship between quantity and price, and a relationship between quantity and the log of price. The latter relationship was suggested by the nature of the residual alloy constraint on the use of scrap in steelmaking. It is possible that demand for scrap is relatively elastic at lower levels of scrap consumption where the residual alloy contaminants present in scrap are more than adequately diluted by large quantities of purer virgin materials. At higher scrap consumption levels, demand may suddenly become inelastic as steel producers begin to run up against constraints which specify maximum permissable levels of various alloy contaminants and are required to incur the costs of removing these alloy contaminants. Initially both specifications were tried. The results obtained with the logarithmic specification were highly unsatisfactory so that this formulation was abandoned.

There was also very little information available which might have suggested a specification for the cross-price relationship. We relied primarily on a linear specification. In addition a number of lag structures were tested in order to see if there might be time consuming adjustment processes involved. The best results were obtained with a six month distributed lag.

A linear relationship was specified between quantity demanded and steel production, the demand activity variable. This was based on the hypothesis that any given percentage increase in steel production, would cause an equal percentage increase in scrap consumption, holding scrap prices and pig iron, prices. constant. Our results were consistent with this hypothesis. (estimated elasticity of demand with respect to steel production was close to 1.0).

Tables 8-4 through 8-6 presents the estimated supply and demand equations for scrap steel. All equations were estimated with two stage least squares using the serial correlation correction discussed in Chapter 10.

The best results were obtained with Model II, using total receipts. of scrap as the dependent variable. In the estimated equations based .on Model II most variables were highly significant and all coefficients had the expected signs. The magnitudes of the estimated coefficients seemed fairly reasonable in most cases.

Attempts to estimate equations based on Model I were much less encouraging. Numerous regressions were run using each of the separate obsolete scrap grades as the dependent variable. We experimented with a number of different data periods, and a number of combinations of independent variables. No equations were estimated in which more than two or three variables had the expected signs and t-ratios exceeding two. Even for these the magnitudes of the estimated coefficients were in most cases difficult to reconcile with some of the. assumptions upon which the model was based. Such disappointing results were likely attributable to the very poor data which exists for separate grades of scrap.

The following discus&ion of results will pertain to those obtained using Model II (Table 8-6).

(1) Demand Activity Variable

Total raw steel production, TSTPRO, was used to indicate the level of activity in all scrap consuming processes. It had a positive sign, as expected and had a t-ratio of 11. The elasticity at the mean, 1.1, indicates that at higher levels of steel production, scrap and virgin

Table 8-3. ECONOMETRIC ESTIMATES FOR MODEL I

	Dependent variable	Independent variables					
		Constant	PHEVY1	TRND	TSTPRO	PPIG	SHREDEX
Supply							
(1)	SHRED	-360	+0.70	+3.6			
			(1.7)	(8.3)			
(2)	SHRED	-356	+0.64	+3.6			-0.02
			(1.5)	(8.4)			(.40)
Demand							
(1)	SHRED	+32.1	+0.42		+.0083		
			(.86)		(2.6)		
(2)	SHRED	+603	-2.3		+0.1	-4.6	
			(3.2)		(3.2)	(4.0)	

Note: All equations were estimated by two stage least squares using an autoregressive correction. T-ratios are in parentheses. Symbols are defined at end of Table.

Variables:

SHRED Receipts of shredded scrap.
PHEVY1 Price of #1 Heavy Melting scrap used as a proxy for the price of shredded scrap
TRND Trend; proxy for increasing shredder capacity
TSTPRO Total steel production
PPIG Price of pig
SHREDEX exports of shredded scrap

Table 8-4. ECONOMETRIC ESTIMATES FOR MODEL I-B

	Dependent variable	Independent variables					
		Constant	PBUN2	BUN2X	TRND	TSTPRO	PPIG
Supply							
(1),	BUN2R	-135	+6.8 (4.7)	-0.18 (1.3)			
(2),	BUN2R	-161	+7.5 (8.9)	-0.35 (3.4)	-1.3 (5.4)		
Demand							
(1),	BUN2R	-139.2	-4.4 (1.2)			+0.056 (2.9)	+4.4 (.88)
(2),	BUN2R	+159.6	-2.07 (.88)			+0.043 (3.6)	

Note: All equations were estimated by two stage least squares using an autoregressive correction. T-ratios are in parentheses. Symbols are defined at end of Table.

Variables:

BUN2R	Receipts of #2 Bundles
PBUN2	Price of #2 Bundles
BUN2X	Exports of #2 Bundles
TRND	Trend: to represent technological change in the scrap industry
TSTPRO	Total steel production
PPIG	Price of pig iron

Table 8-5. ECONOMETRIC ESTIMATES FOR MODEL II

	Dependent variable	Independent variables							
		Constant	PSCRP	PROM	$PSCRP_{lag}$	TRND	TSTPRO	$PPIG_{lag}$	SCRPX
Supply									
(1)	TOTRS	-763	+52.9	+2.6	-10.2	+5.0			-.94
			(9.9)	(4.9)	(1.58)	(5.6)			(6.9)
Demand									
(1)	TOTRS	+601.7	-23.5				+0.30	+9.66	
			(3.7)				(11.0)	(1.69)	
(2)	TOTRS	+1497.3	-22.2				+0.28		
			(3.9)				(1.27)		

Note: All equations were estimated by two state least squares using an autoregressive correction. t-ratios are in parentheses.

Variables:

- TOTRS Total receipts of scrap in thousands of short tons
- PSCRP Price of scrap deflated by BLS wholesale price index
- SCRPX Scrap exports in thousands of short tons
- PROM Proxy for availability of prompt scrap - the Federal Reserve Index of automobile production
- $PSCRP_{lag}$ Proxy for availability of obsolete scrap - Almon lag on prices lagged one to four months
- TRND Trend; proxy for technological change in the scrap industry
- TSTPRO Total steel production in thousands of short tons
- $PPIG_{lag}$ Price of pig iron deflated by BLS wholesale price index treated as Almon lag of five to eight months

materials continue to be consumed in almost the same proportions as at lower levels. Our estimate shows only a slight tendency for consumption of scrap to rise more than proportionately with steel production.

(2) Price of Scrap

The price of scrap, PSCRP, had an elasticity at the mean of 1.4. As we discussed in Chapter 7, interpretation of this parameter estimate raises some problems. Having used monthly data we cannot claim to have estimated a long-run elasticity. (Furthermore, we cannot be certain if this estimate is biased.) On the one hand the fact that adjustments in capital stock cannot be made from month to month suggests that our elasticity estimate may be biased downwards. On the other hand there is the possibility that several months of intensive scrap collection activity, occasioned by sustained high prices, would raise the costs of supplying scrap. Also there is the possibility that monthly changes in the quantity of scrap supplied are especially volatile because of speculative behavior on the part of scrap dealers. These last two factors would suggest that our estimates overstate the long-run elasticity.

In order to get a better estimate of the long-run price elasticity we can take advantage of the fact that we have included in the equation a proxy for the availability of raw scrap in the environment. Conveniently enough this proxy happens to be based upon lagged prices. Thus a lasting price change is felt in our equation not only as a change in present price but also as a change in the proxy variable. BY plugging into the supply equation a postulated permanent one percent change one can compute an elasticity that takes account of some longer-run effects. We need merely sum the coefficient for present price (52.9) and the coefficient for lagged prices (-10.2). The revised elasticity which is computed from the sum of these coefficients is equal to 1.16.

Still it is open to question whether this new elasticity estimate is any closer to the true long-run elasticity. If, as we have implicitly assumed, the proxy $PSCRP_{lag}$ only captures the long-run effect of dwindling scrap availability our problem is not solved. In this case the revised elasticity estimate does not take account of the potentially offsetting effects of long-run capital stock adjustments and short-term inventory adjustments.

What is more likely to be the case is that our proxy variable captures each of the three adjustment effects at least to some extent. However, since we do not know whether four months is sufficient for all three effects to work themselves out completely it is still difficult to say with any confidence whether the revised estimate is higher or lower than the long-run elasticity. Our conjecture is that while four months of high prices is long enough for inventories to become run down, and for the availability of raw scrap in the environment to decline, it is probably shorter than the period of high prices which would be necessary both to convince scrap dealers to undertake capacity expansion and to allow these expansions to actually be completed.

One final factor must be kept in mind when interpreting our estimated price elasticity. An elasticity is a measure of the responsiveness of supply to changes in price in which both quantity and price changes are expressed in percentage terms. Thus, according to our estimate a one percent change in price will produce a 1.16 percent change in the quantity of total purchased scrap supplied (measurements taken at the mean).

Now recall that approximately half of the receipts of total purchased scrap consist of "automatically recovered" prompt scrap. We are not really interested in this half; rather we are interested only in the remainder which consists of obsolete scrap and a small amount of low quality prompt scrap. We have also maintained that changes in the total quantity of scrap supplied, which are produced by changes in the price of scrap, come mainly from obsolete and low quality prompt sources. If we make the strong assumption that the rate at which the automatically recovered prompt is supplied to mills is independent of scrap prices, then it must be that the change in quantity supplied following a one percent change in price comes entirely from obsolete and low quality prompt sources. While total receipts of scrap only increase by 1.16 percent the category obsolete and low quality prompt scrap will have experienced a 2.32 percent increase. Hence the short-run elasticity of the "product" obsolete and low quality prompt scrap would be twice the estimated elasticity which has been stated above

It should be pointed out, however, that an elasticity of 2.32 is an upper limit. The elasticity of the "product" obsolete and low qualtity prompt scrap would only be this high if the quantity of automatically recovered scrap supplied did not respond at all to price changes. Otherwise the quantity of obsolete and low quality prompt supplied would be less than the change in the total quantity supplied. As we have previously mentioned however; short-run price changes are likely to affect the quantity of automatically recovered scrap supplied since scrap dealers can accumulate or draw down inventories in response to such price changes.

(3) Availability of Raw Obsolete Scrap

A four month Almon lag structure on scrap prices, $PSCRP_{lag}$, was used as a proxy for the accessibility of raw obsolete and raw low-quality prompt scrap. The choice of this proxy was based upon the hypothesis that high prices in the recent past would have encouraged intensive scrap collection activities which would leave the reservoir of raw scrap material relatively depleted; conversely, low prices would have permitted the reservoir to build up.

The estimated coefficient for $PSCRP_{lag}$ had the expected negative sign. However this variable turned out to be only marginally significant. The lag structure resembled an inverted "v," with low weights for recent prices, higher weights for two and three-month-old prices, and a low weight for the four-month-old price. We take this relatively poor showing as a reflection of the difficulties encountered in attempting to describe the size and quality of the scrap reservoir in terms of an index which can be used in econometric analysis. While it was argued above that lagged prices furnished the best proxy given the shortcomings of the existing data base, we readily admit that it is far from perfect. For instance it does not take explicit account of the rate at which materials enter the reservoir, the kinds of materials which enter the reservoir, or the location where materials enter.

(4) Scrap Exports

Scrap exports (SCRPX) had the expected negative sign and a t-ratio of about seven. The value of the coefficient, -.94, reassures us to some extent that the system of equations which we have estimated is properly specified. It will be remembered that one of the important simplifying assumptions upon which our model is based is that foreign demand is independent of domestic scrap prices. This assumption allows us to treat exports as an exogenous variable in the supply equation. Were th the assumption not true, exports would be determined simultaneously with shipments to domestic consumers (TOTRS), and prices (PSCRP), by a system of three equations; one for domestic demand, one for foreign demand, and one for total supply. An implication of this assumption is that each ton of scrap exported simply reduces by one ton the quantity of scrap which will be supplied to domestic consumers at any price level. That is, our estimated supply curve, based on quantity supplied to domestic consumers, should shift backwards parallel to itself by one unit for every unit of scrap which is exported. Since SCRPX and TOTRS are given in the same units,the coefficient for SCRPX should be in the neighborhood of -1.0. An estimated coefficient of -0.94 is reasonably close to this value.

(5) Technological Change

The trend variable, which was inserted to capture the effect of changes in technology which lowered the cost of supplying scrap,had the expected positive sign and had a t-ratio of 5.6. The elasticity, .12, indicates that changes in the costs of supplying scrap were barely noticeable on a month to month basis. Working with a period of 11 years the passage of a month represents a change of less than one percent in the variable TRND. An elasticity of .12 implies that holding all other factors constant, including price, the quantity of scrap supplied would increase by less than 1/10 of one percent from one month to the next, or by about one percent from one year to the next. These figures seem rather low indicating that perhaps technological change had a less pronounced impact upon the costs of supplying scrap than is often supposed.

On the other hand it is possible that the effect of some offsetting change, such as rising labor costs, is also picked up in the trend variable. No data was available on wages in the scrap sector so that we were not able to observe the effect of changing technology, while holding fixed all other factors which determine the costs of collecting and processing scrap. Because of the possibility that wages in this sector were rising faster than the general price level, the trend variable cannot be unambiguously interpreted.

(6) Availability of Prompt Scrap

The proxy for availability of high quality prompt scrap, PROM, had the anticipated positive sign and a t-ratio of about five. The elasticity, .2, seems low however, given that the relationship which is supposedly being represented is one between the level of activity in production processes that generate "automatically recovered" high quality scrap and the quantity total scrap receipts. Approximately 50 percent of receipts come from high quality sources. If the return of all high quality scrap were automatic,in the sense that it went directly from fabricating plants back to mills under long-term contracts, then one would expect a one percent increase in production rates of scrap generating activities to cause a one percent increase in the quantity of automatically recovered scrap. Since automatically recovered scrap is approximately 50 percent of total scrap receipts this implied a .5 percent increase in the quantity total scrap receipts and therefore an elasticity of .5.

There are two factors which might account for the difference between the estimated and the expected elasticities. The first has to do with the data. The proxy variable PROM was constructed from a number of Federal Reserve Indexes for sectors that were known to generate large quantities of prompt scrap; included were automotive production, production of appliances and air conditioners, production of transportation equipment, and production of industrial equipment. The amount of prompt scrap generated in activities other than these four is not known with any certainty. If for instance only half of all prompt scrap came from the four sectors represented in the proxy, and the rest was generated at a rate which was not correlated with activity in these sectors,one would expect an elasticity of only .25.

The second factor which might account for such a low estimate has to do with the nature of the relationship being modeled. As we described above in the variables section,some high quality prompt scrap is shipped to scrap dealers before returning to user mills. Because scrap dealers generally hold large inventories,the rate at which this material is generated and shipped to dealers may not be in phase with the rate at which it is shipped from scrap dealers to user mills. When dealing with short intervals of time on the order of one month,it is possible that a relatively constant flow of high quality prompt materials from scrap dealers to user mills might be maintained even though the flow of materials from fabricating plants to scrap dealers fluctuated widely from one month to the next. Such a pattern would result if scrap dealers were in the habit of accumulating inventory when larger than average quantities of prompt material generated, and drawing down inventories when the generation of prompt scrap was unusually low. Behavior of this type would tend to dampen the impact that short-run variations in the rate at which prompt scrap was generated had upon the rate at which prompt scrap was supplied to mills, and hence to explain the low estimated elasticity.

(7) Price of Scrap - Demand

The price of scrap, PSCRP, had a negative coefficient, thereby giving the expected downward sloping demand curve. The price elasticity at the mean was .63.

As was the case on the supply side the estimated price elasticity must be interpreted with some care. It is based upon short-run responses to monthly price changes and therefore may differ from the long-run elasticity. In the short-run steel furnace capacity is fixed so that the choice of input mix is somewhat more constrained than in the long-run. In particular,the quantity of scrap which can be used may be limited in the short-run by the relatively inflexible input requirements of the BOF. A permanent change in relative input prices could,however, induce an expansion of electric furnace capacity thereby increasing opportunities for scrap consumption. (Hence it is likely that .63 under-estimates the long-run price elasticity at least in the vicinity of present scrap consumption levels).

Another problem with our estimate is that while it may be reasonably accurate for short-run price movements over the range into which our observations fall, (there is a possibility that the demand curve drops off quite sharply somewhere beyond this range). The reason for this is that once residual alloy limitations are reached it may be impossible to vary input mixes any further in favor of more scrap without exceeding these limitations.

(8) Price of Pig Iron

Using its present price as an indicator of the cost of pig iron, no significant cross price effect was found. Using a six month distributed lag on pig iron prices some marginally significant results were obtained. The cross price elasticity computed at the mean was .28 with a t-ratio value of 1.69.

This estimate is open to a number of criticisms. First of all, as we noted above in the variables section, there is reason to doubt that reported pig iron prices accurately reflect the marginal cost of pig iron to.integrated steel makers, or even the cost of pig iron to purchasers of merchant pig on the open market. Second, the reason why scrap demand should respond immediately to changes in the price of scrap, but slowly to changes in the price of pig iron,is not at all apparent. 'Therefore it is open to question whether or not the observed relationship between scrap purchases and pig iron prices was a result of pure chance.

IV. ESTIMATION OF TAX IMPACTS

The models developed in the previous section can be used to derive estimates of the impact that the preferential taxation of virgin iron ore, coal and limestone production had on the quantities of steel recycled. Basically we have two alternatives in developing these estimates. One is to use the estimated demand curve and its cross elasticities as representative of the substitutability of scrap for virgin-based inputs. The second is to assume (1) long-run substitutability between virgin and scrap inputs is perfect, and (2) the long-run supply of virgin inputs to steel production is elastic, and base the recycling estimates on the supply curve for scrap steel products.

In the first approach, which is properly termed a short-run viewpoint, we use the estimated elasticity of the demand for scrap steel with respect to the price of pig iron to derive the impact of the preferential taxation of virgin iron, coal and limestone production on the demand for scrap steel inputs. This elasticity was estimated as .28, subject to the qualifications noted earlier. In Chapter 6 we estimated the impact of the tax subsidization of virgin steel input production at at most three percent of the price of pig iron. This indicates the demand curve for scrap steel might rise by .28 x 3% = .84% should the tax subsidies be eliminated. A shift in demand of this magnitude would increase the price of scrap steel by $.84[Ed/(Ed + Es)] = .84[.63/(.63 + 2.32)] = .18\%$, where Ed and Es refer to the elasticities of demand and supply respectively. The quantity of obsolete scrap steel recycled would increase by the change in price multiplied by the supply elasticity, or .18 x 2.32 = .42%.

In the second approach, which is properly termed an optimistic long-run assessment, we need only multiply our estimate of the long-run supply elasticity by the change in the price of virgin-based inputs to derive the upper limit on the quantities of obsolete scrap steel which would be recycled should the tax subsidization of the inputs to pig iron production be eliminated. This estimate of 2.32 x 3% = 6.4% is biased upwards, not only because of the computations underlying the figure of a three percent tax impact on price, but also because of the assumption of long-run substitutability of scrap steel for pig iron. Residual alloy contamination, though remediable at the cost of slowing the steel making process, makes scrap steel a less desirable input and even in the long-run will limit" the substitutability of the two inputs.

CHAPTER 8
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CHAPTER 9

PAPER

The paper industry utilizes virgin wood pulp and recycled scrap paper to produce a wide variety of products for final consumption. The fraction of all paper products eventually recycled has been declining irregularly for the past 25 years. In 1950 approximately 28 percent of all paper products were recycled, but by 1973 the recovery ratio had fallen to 17 percent.[1] In addition, the market for wastepaper is characterized by violent price swings. For example, within a recent twelve month period the dealers' price ranged from $43 to $4 per ton.

This chapter investigates the flow of materials through the paper industry and the nature of competition between primary and scrap materials as inputs to the paper industry. An econometric model of the wastepaper industry is specified and estimated, and, finally, we compute the impacts of the preferential taxation of the forest products industry on incentives to recycle wastepaper.

I. INPUTS TO THE WASTEPAPER INDUSTRY

Raw material inputs to the wastepaper industry originate during the fabrication of paper products and after paper products are used by consumers. The first category of inputs is termed "pre-consumer," "industrial," or "prompt" scrap. The latter category of inputs is normally termed "post-consumer," or "obsolete" scrap. Industrial scrap is generated in converting or fabricating operations which produce intermediate or final paper products from paper or paperboard. Post-consumer wastepaper. is that discarded by commercial, institutional, and residential consumers of paper and paperboard products.

A. Industrial Scrap

Depending on the fabrication stage, material from industrial sources may be almost identical to that coming off paper and paper board machines. In integrated mills, this material is routinely recovered and processed for blending with virgin wood pulp. In most cases this material requires only collection, aggregation and transportation to user mills. However, in some operations, industrial wastepaper will be combined with coatings or adhesives which will require additional processing before the fiber is acceptable as a production input. This processing is not performed by the wastepaper industry as defined here, but by the user mills.

The major advantages of industrial sources are large volumes of homogeneous residual materials, their low or at least predetermined levels of contamination, their proximity to users, and disposal practices which preserve the economic usefulness of the material.

While it is generally assumed or calculated that perhaps 85 percent to 90 percent of industrial wastepaper is recycled, this figure does not apply equally to all product lines because of differences in concentration of sites, contamination, and homogeneity of discard streams.

The distribution stage, between fabrication and use, contributes a portion of the industry's resource base which shares characteristics of prompt and post-user wastes. This category of residuals generation includes over-issues of the printing and publishing sector, and inventories of obsolete paper products. Materials from this stage are usually homogeneous, and contamination may not be significantly different from that found at the converting stage. However, low average size of discard streams and more numerous and scattered sites may not permit low cost recovery of separate raw materials.

B. Post-Consumer Scrap

The post consumer source of wastepaper generates by far the greatest volume of material, and availability does not appear to be a constraint upon increased recovery. However, due to lower concentrations of generating sites, less homogeneous flows and higher levels of more intractable contamination, recovery is more costly and materials are generally of lower value.

The post-consumer source includes several sub-classes of generating site: commercial, institutional, and residential. The types of material residuals, the volume and homogeneity of discard streams, and the types and levels of contaminants are quite distinct between the two classes. Commercial and residential generators are different also in degree of site concentration and internal housekeeping practices which may affect the feasibility of recovery.

Banks, office buildings and retail outlets generate high volumes of relatively homogeneous wastepaper, often of high quality paper products low in contaminants. This permits economical segregation of materials at the generating site, compacting for ease of storage and handling, and high density collection activities. Furthermore, on-site preparation of some materials, e.g., corrugated containers, is often not significantly more costly than for disposal.

Residential waste materials are more often mixed, heavily contaminated in use, and require more handling services per unit recovered. One exception to this appears to be newspaper, which may be more difficult to discard regularly in combination with other refuse than to accumulate and discard separately.

II. DEMAND FOR WASTEPAPER

This section reviews the various production processes which use wastepaper as an input and factors influencing the substitutability of secondary for virgin fiber. Strength and cleanliness or brightness requirements in end-use applications appear to have the greatest impact on the acceptability of paperstock fiber. The use of high speed forming machines turning out standardized products may also impose strength and contamination requirements which adversely affect the use of paperstock. Certain product characteristics imparted by the forming machines predominantly used in the industrial sector utilizing paperstock may put these products at a technical disadvantage in some uses. Finally, since 1945, most new productive capacity has been built near sources of virgin pulp inputs imposing a transportation barrier to the use of more secondary fiber, at least in the short-run.

The demand for paperstock (graded wastepaper) as a raw material input is derived from demand for the outputs it is used to produce. These outputs may be intermediate producers' goods or final consumer goods. Paperstock provides about twenty-two percent of the fiber used in the manufacture of paper and paper board. Neither its use nor its importance relative to other fiber sources is distributed evenly across all production categories.

The demand for paperstock is in fact an aggregation of demands for different paperstock grades, derived from the requirements of various production processes. Different product lines require different mixes or blends of paperstock fiber, used alone or in combination with virgin wood pulp fibers. Conversely, the use of specific paperstock grades may be concentrated in a few distinct product lines for which the given grade provides the appropriate fiber characteristics. Since product lines within the paper and paperboard industries vary widely in end-use applications, this means that the market conditions for some paperstock grades will be quite different from those of other grades.

Paperstock is a source of cellulose fiber of various types, and thus competes with other fiber sources - principally virgin wood pulp. Paperstock fiber competes with virgin fiber in the input market as a substitute raw material. In intermediate and final goods markets products made from paperstock fiber compete with those based on virgin fiber.

Paperboard production accounts for approximately 75 percent of all paperstock consumed.[2] Materials are drawn from both industrial and post consumer sources. Boxboard accounts for by far the largest portion of paperstock used in paperboard production, although corrugating medium is also an important consumer of paperstock, both in terms of current levels and potential for growth. The paperboard sector has experienced a high growth rate over the last two decades, mostly in linerboard output which has grown at an average annual rate in excess of 5.5 percent.[3] The other growth component of the sector has been special foodboard, a solid virgin fiber product, which has displaced paperstock-based (combination) boxboard from a substantial share of the growing market for food packaging. These two product lines use very little paperstock, accounting for the declining relative importance of paperstock fiber in the paperboard sector and in the industry as a whole.

The historical trend in paperboard categories using paperstock is suggested in the figures below:

Table 9-1

Percent total fiber from paper stock

	1961	1971
Boxboard	83.4	64.8
Linerboard	11.7	2.2
Corrugating medium	21.5	19.1

Source: Secondary Fiber Recovery Incentive Analysis, Resources Planning Institute.

Combination (secondary fiber) boxboard is made entirely from paperstock inputs and includes all grades of paperstock. It is formed in layers on multiple-cylinder machines; previously market wood pulp was used for the outer laminations, but high grade paperstock has replaced wood pulp in this use. The cylinder machines impart fiber alignment in the direction of cylinder rotation; this reduces tear strength in the machine direction. Kraft boxboard is produced on Fourdrinier machines which reduce the fiber alignment.[4] The importance of this difference in establishing market shares is difficult to determine. While combination boxboard could presumably be produced on Fourdrinier machines, little experimentation has been conducted in this area.

Plants incorporating cylinder machines and using paperstock were formerly used by the virgin-based sector drawing upon forest of the Northeast regions. They are located near urban populations which generate the necessary paperstock supplies. Fourdrinier capacity is located near to the more recently (post World War II) exploited virgin resource base in the South and Northwest, remote from paperstock sources. These machines are of large capacity compared with cylinder operations, and run continuously at high speeds producing standardized products.

Corrugating medium is the second most important consumer of paperstock, and the one area in which paperstock inputs may grow in relative importance. Corrugating medium is produced by Kraft, semi-chemical (NSSC), and recycling processes. The last of these uses a 100 percent paperstock input, primarily corrugated obtained from both prompt and post-user sources. The semi-chemical process, which involves chemical pre-treatment of the bulk wood and mechanical separation of fiber, uses primarily hardwood stock which has shorter fiber than the softwoods which predominate in the Kraft process. The semi-chemical process routinely includes corrugated as a fiber supplement. After repulping, the softwood fibers which predominate in corrugated materials still compare favorably with the shorter hardwood fibers. Recycled fiber used exclusively or in combination with virgin fibers provides technical advantages in performance on the corrugating machine, and end-to-end strength.

Linerboard, the major growth product in the paperboard sector, uses negligible amounts of paperstock, and that used is industrial scrap obtained from integrated converting operations. Recycled linerboard from cylinder machines appears to be at a technical disadvantage in competition with Kraft liner with respect to burst strength, which is a function of fiber length and the forming process. The disadvantage is greatest in the lower calipers (thicknesses); compensation may require up to 25 percent more fiber by weight., resulting in production cost and use disadvantages. The burst strength parameter is specified in a code of standards for shipping containers, and manufacturer's adherence to such standards affects liability in cases of loss in transit. Whether the specified parameter value is related to product performance is unclear.

In the paper sector of the industry, paperstock is used in products which rely on pulp fiber types similar in most technical features to paperstock fiber.[5] Both groundwood (mechanical fiber separation) pulp and semi-chemical hardwood pulps produce short fiber length and contain various wood substances which are removed in the full chemical pulping processes. Paper products consume approximately 16 percent of all paperstock supplied. Most of this is high grade industrial paperstock, much of it acquired through self-developed, captive converter sources. An important exception is recycled newsprint, which uses post-consumer newspapers.

Printing and writing paper, including newsprint, consumed approximately seven percent of all paperstock, from which six percent of total fiber requirements were obtained. Within this group, recycled newsprint uses almost all post-consumer scrap. The remainder of paperstock consumed goes primarily to tissue and sanitary papers, where in recent years it has provided 25 percent to 30 percent of the total fiber requirements.

Recycled newsprint appears to be equal or superior to virgin newsprint in all technical characteristics, and can be marketed profitably at a 10 percent discount form the virgin price. Over two-thirds of the newsprint consumed in this country is imported from Canada; much of this is obtained from subsidiaries of U.S. newspaper publishing firms.

The remaining sector of the paper and paperboard industry is construction paper and board. Within this sector only construction paper employs paperstock, which provides about 70 percent of fiber requirements. This category consumes about nine percent of total paperstock.

Technological and organizational developments in the paper and paperboard industry over the last forty years have restricted the range of substitutability between secondary and virgin fiber. Industry growth has been dominated by large firms, vertically integrated from timber owning and harvesting through pulp manufacture, paper and paperboard production and often into final product fabrication. Pulp mills in combination with paper and paperboard machines represent a very capital intensive production process, located near sources of virgin fiber and remote from paperstock sources. The introduction and development of the Kraft pulping process has permitted pulping of a greater variety of wood species and use of primary wood processing residues, thus lowering costs of virgin material use. Chemical by-products of the process have rendered virgin-based production even more attractive.

Mills which rely wholly or in part on paperstock fiber usually employ older, low capacity cylinder machines once used by the virgin-based paper and board industry drawing upon the forest resources of the Northeast and Northcentral regions. Product characteristics imparted by these machines are often alleged to be the cause of the deteriorating position of paperstock relative to virgin fiber, particularly in the major industry growth sector, linerboard.

Presently about 80 percent of paper and paperboard capacity is not equipped to handle paperstock. Mills using paperstock may employ special de-inking equipment, or special pulping facilities designed to disperse the more intractable contaminants. New paperstock re-pulping technology has been developed in Europe and Japan, but has not been introduced to any large extent in the United States.

Possibly of greater significance is the availability of paper and paperboard forming machines which are capable of accepting a greater variety of paperstock fiber, operating at higher speeds and imparting fewer undesirable characteristics than do the cylinder machines. Again, little of this type of capacity has been brought on line in this country.

Since expanded use of paperstock appears partly contingent upon mix and location of the industry's capital stock, adjustments to changes in relative fiber prices or availability conditions may require many years.

III. ECONOMETRIC SPECIFICATION AND ESTIMATION

A. Specification

The quantity of paperstock demanded as an input to the production of paper and paperboard is hypothesized to depend upon:

1) Price of paperstock
2) Price of market wood pulp, the principal substitute fiber source
3) The level of activity in the sectors of the paper and paperboard industry using paperstock as an input
4) Prices of other inputs to the production of paper and paperboard
5) Characteristics of the capital stock in the paper and paperboard industry affecting the ease and extent of substitution between secondary and virgin fiber

It was hypothesized that the quantity of paperstock supplied in any period would depend upon the following:

1) Price of paperstock
2) The availability and accessibility of raw materials required as inputs to the wastepaper industry
3) Prices of other inputs to collection, processing and storage activities of the wastepaper industry
4) Characteristics of the capital stock used in the supply process.

The. following section discusses the effects these variables are expected to capture, the empirical measures used, and the form in which the variables are included in the estimated equations. A later section will present the estimation results and their interpretation, and discuss assorted problems related to the estimation of parameters and the inferences to be drawn from them.

(1) Quantity of Paperstock

Modeling the wastepaper market in an empirically testable form is complicated by the fact that supplies of scrap are derived from two sources, industrial and post-consumer, and the parameters which affect supplies from these two sources are different.

The empirical measure used for the quantity of paperstock is taken from the monthly Current Industrial Reports, Series M 26 A, published by the Department of Commerce. The reported figures are for raw tonnage of paperstock consumed at user mills, all grades combined. These figures exclude some industrial wastepaper which is transferred internally in plants which combine paper or paperboard manufacturing with converting operations. However, the measure includes that portion of industrial wastepaper supplied by sources external to the user firms.

A series on inventories of paperstock at user mills is also available from the same source, permitting adjustment of consumption figures to receipts of paperstock. Receipts of paperstock are calculated to be equal to consumption plus the month to month change in reported inventories.

(2) Price of Paperstock

The price of paperstock is included in both the supply and demand equations. In keeping with the level of aggregation of the model, we used a composite price for paperstock of all grades as reported by the Bureau of Labor Statistics in "Wholesale Prices and Price Indexes". The price is based on weekly quotations for the separate grades in four regional markets.

Prices are brokers' buying prices for large quantities, f.o.b. dealers' yards. Thus these prices are not the prices paid by user mills, which would include transportation charges from dealers' yards to mill sites, and brokers' profit. The price series is not totally satisfactory as a measure either of the price received by the suppliers of paperstock, or of that paid by users. Other prices used in the model are delivered prices. The omission of transportation charges from the price of paperstock can introduce specification errors in the tested model, with resulting bias in the estimated results. This problem will be considered in the section reporting the econometric results.

(3) Price of Woodpulp

Within the range of technical substitution possibilities available to them, the operators of an existing mill choose between paperstock and virgin wood pulp in determining their fiber source mix. The price of wood pulp is included in the demand equation to reflect these substitution possibilities and to obtain an estimate of the cross-elasticity of demand for paperstock with respect to the cost of obtaining wood pulp.

The wood pulp price applies only to market wood pulp, approximately 10 to 15 percent of pulp production. The price measure used (from BLS, "Wholesale Prices and Price Indexes") is a composite of prices for a number of wood pulp grades. Most of the marketed pulp for which prices are reported goes to the production of paper or types of paperboard in which only small amounts of paperstock are regularly used. Major. paperstock consumers use small amounts of wood pulp, and much of this is probably low grade pulps and screening for which market prices are not reported, or not included in the composite price index. In addition, the groundwood price did not change over the period for which the models are tested; yet, this type of pulp is one for which paperstock provides a fairly close substitute.

The goundwood price component represents an extreme case of a more general problem with the reported prices of woodpulp: very little variation in the reported prices occurs for the period studied. These prices may be viewed as posted or list prices set by the oligopolistic pulp-producing sector of the paper and paperboard industry. This price is often discounted when pulp production exceeds requirements at integrated mills and surpluses are placed on the market. In times of shortage, actual selling prices may be marked up considerably, or available pulp rationed to customers. Thus, the reported price is not altogether a satisfactory indicator of the cost of obtaining wood pulp.

Several possible methods of dealing with this difficulty were considered. The first approach involved replacing the reported price of wood pulp with proxies representing pulp scarcity conditions more accurately. These proxies included wood pulp capacity utilization, the ratio of pulp production to total paper and paperboard production, and the ratio of pulp inventories to pulp shipments. These proxies would of course represent ordinal changes in the cost of obtaining wood pulp, and cannot easily be related to cardinal values which are required to compute meaningful cross-elasticities of demand.

The second approach involved replacing the reported price of wood pulp with prices which would reflect more accurately the actual price at which pulp could be acquired in the market. Possible replacements included the price of pulpwood, the principal raw material input to the production of wood pulp, on the grounds that this price was generated. in a more competitive market and that scarcity conditions for wood pulp would parallel those for pulpwood. There is no monthly price series for pulpwood. The annual series of pulpwood prices suffers from discontinuities, as well as incomplete coverage of pulpwood species, regional markets and types of purchase arrangements.

The relationship between pulpwood prices (stumpage or delivered cords) and the price at which customers acquire pulp is clouded by industry structure, the increasingly heavy use of residues in pulp production, and the existence of large pulpwood inventories.

An alternative surrogate for the price of wood pulp is the price of the Pulp Substitute category of paperstock. Since this material is a close substitute for wood pulp, actual market prices for the two should be in equilibrium, separated by a constant processing cost differential. Since much of the pulp substitute paperstock is acquired through non-market channels, its price may share some of the shortcomings noted for the price of wood pulp. The pulp substitute price does display less variation over time than those of the bulk grades. An equation was estimated using this replacement for wood pulp price. Discussion of the substitution and related adjustments in other variables is contained in the section on econometric results.

(4) Activity in Paperstock Consuming Sectors

Two sectors, combination paperboard and construction paper, consume by far the major proportion of the bulk grades (news, corrugated, mixed) handled by the wastepaper industry. With the exception of recycled newsprint, most of the paperstock used in paper production is industrial, obtained from converter plants under long term contractual arrangements. Some corrugated, again mostly industrial in origin, is routinely used in semi-chemical corrugated production. Together, combination paperboard and construction paper use almost 85 percent of paperstock consumed.

A monthly series for construction paper and board output is available from the Department of Commerce “Current Industrial Reports,” Series M 26 A. Regrettably, a monthly series for combination paperboard is reported beginning only in 1968. It was thus necessary to construct a comparable series for the years 1960 to 1967.

Annual data in the American Paper Institute’s “Statistics of Paper and Paperboard” have been reclassified to conform with the combination paperboard reporting category introduced by the Census in 1968. The construction of a monthly series for combination paperboard relied upon the API annual percentage distributions of certain paperboard categories between combination and virgin-based paperboard.

The monthly combination paperboard series was constructed by adding together the monthly series for folding boxboard, set-up boxboard, container chip and filler board. To this was added a percentage of corrugated container and linerboard outputs, using the annual percentage distributions in the annual reclassified data series. Special foodboard was excluded from the combination paperboard category. This series was tested for internal consistency, and the results indicated that the reported and constructed series measured the same quantity. A discussion of this testing procedure follows.

<u>Construction of the combination paperboard series, test for consistency</u>

The measure of activity in the combination paperboard sector was constructed by splicing the monthly series for this category reported in the Department of Commerce “Current Industrial Reports” for the period January 1968 to August 1974 with a series compiled from reports for sub-categories from. January 1961 to December 1967, from the same publication. The sub-categories have been listed in the earlier discussion of this variable. The categories to be included were checked with Census bureau personnel in charge of the reclassification and with the chief economist for the American Paper Institute, Dr. Benjamin Slatin.

This series was tested for internal consistency in the following way: Two new variables were defined, one taking the values for the combination paperboard series (compiled) from January 1960 to December 1967 and the value zero from January 1968 to August 1974; the other was assigned the value zero from January 1960 to December 1967, and the (reported) values for combination paperboard from January 1968 to August 1974. Both variables were used together to replace the single (constructed plus reported) series for combination paperboard in the demand equation. Estimation of this demand equation produced coefficients and t-statistics for each of the new variables very close to those obtained in the equation estimated using the single (constructed plus reported) combination paperboard series. The coefficients and t-statistics for the remaining variables remained the same for both equations. Comparison of the estimated results is displayed below:

CMBPBD (Combination paperboard series January 1960 to August 1974)

Coefficient: 1.109

t-statistic: 13.298

CMBL (January 1960 to December 1967) = 0

(January 1968 to August 1974) = CMBPBD

Coefficient: 1.15

t-statistic: 13.742

CMBL (January 1961 to December 1967) = COMBPBD

(January 1968 to August 1974) = 0

Coefficient: 1.21

t-statistic: 13.459

<u>(5) Availability and Accessibility</u>

<u>(a) Industrial scrap</u> The availability effect refers to the impact that variations in amounts of material physically available can have upon the market supply of paperstock. The component of the paperstock supply derived from industrial sources is that most likely to be affected by material availability.

Generators of prompt wastepaper provide fairly high volume, homogeneous material flows which suggests a relatively brief turnaround time from generator to user since aggregation and processing requirements are low. Usually these materials are acquired through long-term arrangements with "captive" suppliers. Thus there is a component of the measured industry supply flow which is quickly, routinely and completely recovered - within the established supply network - and which is likely to be influenced by the amounts of material available for recovery, rather than by industry response to price incentives.

Accurate specification of the supply relationship, where the dependent variable does include a significant component from this source, should include an indicator of raw material availability. This material is generated at the converting or fabricating end of the production sequence; thus, an indicator of activity at this stage should be included in the supply equation. Direct measures of the amounts generated, or calculation of the percent of material throughput generated as wastepaper over time are not available.

There remain the questions of which empirical measure to employ, and how the time-form of its relation to the dependent variable should be specified. As a measure of the availability of the prompt paperstock component we have used the Federal Reserve Index of production at the converting stage for paperboard containers and converted paper products. The index used, IPBP, is a simple average of the indexes for these. two sectors. Other factors held constant, an increase in measured activity an increase in measured activity at this stage is expected to have a positive influence on the quantity supplied. The supply relationship to be empirically tested must specify when this impact on supply is to occur, relative to the time at which the material is generated.

It is reasonable to expect that any current effect on industry supply activity is the result of an earlier change in material availability.

If the data periods are lengthy relative to the turnaround time for prompt scrap (e.g. annual), same period levels of activity in the prompt-generating production stage would be appropriate. If the data periods are brief relative to turnaround time, (e.g. monthly),aCtiVity variables should be lagged the appropriate number of time periods from that in which the effects of changes in activity are to be realized. The lags specified in the estimated equations are fixed, one month lags.

Since the time interval between production of paper and paperboard and the fabricating of paper products which generates prompt scrap may be quite short, it is conceivable that indicators of activity in the prompt-generating operations will be closely associated with indicators or measures of activity in the consuming sectors. This opens the possibility that independent explanatory variables in the demand equation will be duplicated in the supply equation. However, a model tested with monthly data and specifying a time-lagged relationship between availability and impact on supply would permit more effective separation of the supply and demand relationships.

The inability to separate effectively the supply and demand specifications in the model which was estimated with annual data may be a principle reason for the unsatisfactory results which were abtained.

The use of a fixed period lag between the occurrence of generating activity and the hypothesized effect on the industry supply curve assumes that the time relationship is invariant. However, some slack may be introduced into this otherwise taut sequence by speculative behavior on the part of dealers and brokers. If speculators feel that prices for outputs derived from prompt materials are likely to move upwards in the near future, they may hold supplies off the market in anticipation of these higher prices. If they anticipate that prices are likely to decline, leaving them with bulky perishable inventories of lower value, they may attempt to unload quantities at a higher rate than otherwise. This type of behavior will alter the time relationship between the indicator of availability and the supply shift effect of changes in availability.

(b) Post-consumer scrap The earlier general discussion of supply suggested that availability of obsolete or post-consumer wastes was far less likely to operate as a shifter of supply than in the case of industrial scrap. In general, the physical amounts of post-consumer wastes are very large in comparison with the amounts recovered. Characteristics of post-user wastes other than simply the amounts of material discarded must have some bearing on the amounts and mix of materials recovered from this source. These other characteristics are grouped under the term "accessibility" and include the spatial and size distribution of materials deposits or generating sites, and the composition of waste streams or reservoirs. Changes in these characteristics from period to period may be expected to have an effect upon the costs to the industry of obtaining suitable inputs, and thus have an impact upon the industry's supply of outputs. Although the notion of a reservoir stock of discarded products and production. residuals awaiting collection and processing appears less appropriate for the wastepaper industry than for the less perishable ferrous and non-ferrous scrap materials, it still may be desirable to account for this effect in the supply equation for paperstock.

While changes in the characteristics of the wastepaper resource base, in particular the post-user component, cannot be measured directly, it is possible to relate industry activity to changes in these characteristics.

Assuming that the wastepaper industry behaves rationally and exploits the most accessible sources of inputs first, high levels of recovery acrivity in one period could temporarily shift the industry supply curve upward to the left in succeeding periods as a result of decreased accessibility of materials remaining in the resource base. Although there is no relatively long-lived stock of discarded wastepaper awaiting collection in more or less disadvantageous locations or conditions, there are a number of junctures in the supply process where inventories of discarded materials may be accumulated, and depletion at these holding points could temporarily disrupt the regular flow of wastepaper inputs to dealers, or require greater collection and processing costs to maintain a given flow of paperstock in later periods. Moreover, dealers' and brokers' inventories of graded scrap outputs or materials in process could become depleted in periods of intensive supply activity, resulting in or contributing to a temporary backward shift of the supply curve.

To reflect this effect, a variable incorporating a lag structure imposed on past prices of paperstock (period t-1 to t-4) is included in the supply equation. The expected sign for this variable is negative, indicating that high recovery efforts in the past, represented by high past prices for industry outputs will lead to higher recovery costs and a backward shift in supply for some number of succeeding periods.

This proxy variable of course does not measure directly the changes in the concentration or homogeneity of waste flows tapped by industry efforts. Such changes can shift the accessibility gradient presumed to be exploited rationally by the industry. This means, for example, that seasonal alterations in concentration or homogeneity might disturb the expected relationship between lagged prices and current supply.

(6) Other Variables

The cost of certain inputs to the process of supplying wastepaper was proxied by a data series on the wages of sanitary workers. This variable proved insignificant in all specifications. An additional cost of using wastepaper is the cost of transporting the material to the user facilities. Accordingly we included a series on railroad freight rates in the demand equation. It too proved insignificant in all specifications. No variables were found which would represent an index of the capital stock of the users or suppliers of paperstock.

B. Econometric Estimation

Before presenting the econometric estimates of supply and demand, we will devote a few paragraphs to considerations underlying our choice of period for the analysis and the frequency of observations.

Short-run adjustments in the wastepaper industry take place rapidly, so that many of the behavioral relationships being modeled occur within a period of months. As a result, the use of annual or even quarterly data entails considerable loss of information on the adjustment mechanisms and their timing. On the other hand a distributed lag model using annual data would be required to capture the long-run effect of changes in relative prices on investment decisions in the industry. Ultimately, data availability restricted our observation interval to one month. Data on many of the important variables were available for periods of fifteen years or less, effectively precluding the estimation of a distributed lag model using annual data. A side benefit from the use of monthly data is that it permits the separation of industry activity variables and availability of raw materials in the specification of supply and demand. The relationship between the results obtained with monthly data and the longer-run adjustments of interest for policy purposes will be discussed following the presentation of econometric results.

The monthly data we obtained were not seasonally adjusted. Although seasonal adjustments are made routinely for many monthly time series, our data had not been adjusted. Before we proceeded to perform these adjustments, we deemed it prudent to examine further whether, in fact, such adjustments were desirable. The use of non-seasonally adjusted data relies upon the assumption that the specified equation is equally applicable to all observations.

The demand equation, in particular, includes a number of variables affecting the use of paperstock, all of which could include a common seasonal element. Examination of the production figures for the major paperstock consuming sectors indicates a seasonal slackening of activity in the summer months.

The appropriate hypothesis to test is whether the intercept for an estimated demand relation incorporating a seasonal dummy variable is significantly different from the intercept of an equation estimated without a seasonal dummy variable (see Johnston, p. 179).[6] The dummy variable for the demand equation was defined to have the value one for the month of July in each year, and the value zero for all other months. The statistical comparison indicated there was not a significant difference, therefore, the use of non-seasonally adjusted data appears to be appropriate.

Estimated supply and demand equations for two models of the wastepaper industry are presented in Table 9-2. In the first model the dependent variable for both supply and demand was the consumption of paperstock, whereas receipts of paperstock, which equal consumption plus changes in inventories, were used as the dependent variable in the supply equation of the second model. In the second model demand is disaggregated into two components, consumption and changes in inventory holdings. The cunsumption equation is identical with that reported in the first model. We were unable to estimate a satisfactory inventory adjustment equation, and consequently have not reported one as part of the second model.. The equations were specified as linear and additive in the independent variables and were estimated by two stage least squares.

(1) Demand

All variables have the expected sign in the demand equation. With the exception of the price of wood pulp, coefficients are significant at the 0.01 level; for price of wood pulp, coefficients are significant at the 0.05 level? The less favorable t-statistic for this variable may be related to the unsatisfactory nature of the data series.

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* See Chapter 10 for a more thorough statement of statistical significance under two stage least squares.

Table 9-2

SUPPLY AND DEMAND FOR WASTEPAPER

(January 1961 to December 1972)

Variable	Constant	PP	PWP	QPBD	QCP	IPBP	L
Model I							
demand (consumption)	49.1	-.13 (2.37)	+.11 (1.94)	+.51 (6.20)	+1.11 (13.30)		
Supply (consumption)	457.7	+.46 (10.62				+.31 (3.03)	-.40
Model II							
Demand*							
Supply (purchases)	450.0	+.40 (8.89)				+.32 (2.25)	-.34

* Identical to Model I.

Variables:

P — The BLS index of paperstock prices, divided by the BLS wholesale price index (times 1,000)

PWP — Composite wholesale price index of woodpulp divided by BLS wholesale price index (times 1,000)

QPBD — Production of construction paperboard in thousands of tons

QCP — Production of combination paperboard in thousands of tons

IPBP — Federal Reserve Index production of converted paper products and paperboard contains production (times 10)

L — An Almon lag on one through four month old prices of paperstock

(t-ratios in parentheses)

Dependent Variable: Consumption or purchases of paperstock in thousands of tons

The estimated coefficients appear to be of the correct magnitude, where independent information permits comparison. Information on construction paper and board and on combination paperboard, regarding the percentage of fiber content obtained from paperstock and the percent of total paperstock consumed by these sectors is available from a cross-section industry survey conducted by McClenahan for the two-year period 1969-70.[7] According to the survey, approximately twelve percent of paperstock consumed is used in construction paper, where it accounts for two-thirds of production, by weight. Since the measure of activity in this sector included output of construction board which uses no paperstock, the coefficient should be less than two-thirds. The estimated coefficient (0.51) conforms with this expectation. The significance assigned to this coefficient lends weight to the opinion of numerous industry observers that the fortunes of the paperstock market are closely related to movements in the construction industry. This would of course be more relevant to the market situation for the bulk grades than for the high grades which are not used in this sector.

The McClenahan cross-section survey indicated that approximately 1.15 tons of paperstock is required for each ton of combination boxboard produced - the result of weight losses during processing. Combination boxboard is by far the major component of the combination paperboard sector whose activity is measured by QCP. This estimated coefficient of 1.11 is compatible with this information.

The calculated elasticity for paperstock demand with respect to its own price is 0.16. This result also is not unexpected, given the characteristic division of users and non-users of paperstock, particularly in terms of large-scale use. Substitution of paperstock for pulp fiber may indeed occur to a significant extent, as it did in the replacement of virgin fiber with high grade paperstock in the outer layers of laminated combination boxboard, but this effect would not be closely related to monthly variations in price of paperstock.

The cross-elasticity of demand for paperstock with respect to the price of wood pulp, evaluated at the means, is 0.13. This does not seem to be unreasonably low, since most of the paperstock consumed is used in mills which customarily obatined 100 percent of their fiber requirements from this material; other users rely primarily upon captive long-term supply arrangements with prompt sources or dealers to supplement wood pulp inputs with high grade paperstock. Neither group is expected to shift its mix of fiber sources appreciably in response to short term price changes. Longer-run responses to changes in relative prices might be appreciably greater, however. The positive sign for the wood pulp price indicates that an increase in the price of wood pulp will positively affect demand for paperstock through substitution of the relatively cheaper fiber source.

If we assume that the error resulting from the use of an inaccurate wood-pulp price series is independent of errors in the other independent variables, the bias in the estimated coefficient is downwards towards zero. Consequently, the estimated coefficient and calculated elasticity for the‘price of wood pulp are likely to be below the true value, understating the effect on paperstock demand resulting from an increase in the price of substitute virgin wood pulp.

A demand equation was estimated using the price of pulp substitute grade paperstock as a surrogate woodpulp price, on the grounds that this would be in equilibrium with the actual market price of woodpulp, separated only by a processing cost differential. Since the price of this paper-stock grade is incorporated in the composite paperstock price used in the reported equations, a new composite paperstock price variable was constructed by averaging the prices of the three remaining bulk grades of paperstock. The new equation was estimated, but the coefficient for the pulp substitute grade of paperstock proved insignificant.

The demand relationship as specified omits several variables for which there exist no suitable data series. This omission may bias the estimated coefficients for the variables which are included.

Transportation charges are an example of a variable which should be incorporated in the full cost of obtaining paperstock. Two attempts were made to include transportation charges in the estimated demand equations. The annual average freight rate series (revenue per ton mile, all commodities, from ICC annual reports) was converted to a monthly series in the following manner. The annual average rate reported for each year was taken as the year end rate. The change from year to year was assumed to be smoothly distributed over the twelve month period. The calculated monthly freight rates were then converted to an index, with the average for 1957-59 as the base period. These rate indexes were then deflated using the WPI for all commodities.

Two new paperstock prices series were constructed, one allocating half of the full cost of paperstock to freight rates and the other allocating 30 percent to freight rates.

Demand equations were estimated using each of these paperstock price series. An additional equation was estimated including the constructed freight rate series as a separate variable, the cost of an input complementary to the use of paperstock. No satisfactory results were obtained with any of these equations.

(2) Supply

All estimated coefficients have the expected sign in the supply equation, and are significant at the 0.01 level. The elasticity of supply with respect to the current price, calculated at the mean, is 0.40. The sign and magnitude of the coefficient for the Almon lag structure imposed on past prices indicate that the elasticity with respect to price changes that persist for a few months. While response is positively related to current price, it is negatively related to past prices. The net longer-term elasticity is about 0.15.

The price elasticity estimates are consistent with considerable inertia in supply activity. Sustained price changes might well be met with considerably greater supply responsiveness than is indicated by our elasticity estimates, but the effect of long run adjustment does not unambiguously favor appreciable increases in supply elasticity, While investment in new capital and equipment will affect long-run supply responses, this factor may be partly offset by declines in material availability from prime sources and increased costs of recovery as exploitation extends beyond the most accessible materials.

The interpretation of the lag variable is obviously crucial to the use of these results for predictive purposes. The inclusion of a lag structure on past paperstock prices and lagged variables indicating activity levels at the prompt-generating production stage was supported in the discussion of model variables as an effort to accommodate some aspects of the supply process peculiar to the scrap industry.

The two separate variables are designed to capture the effect on supply of changes in the raw material resource base exploited by the wastepaper industry. The resource base for the wastepaper industry comprises flows from two reasonably distinct sources: industrial and post-consumer.

Apart from inventories of prepared paperstock held by dealers and brokers, and points at which residuals are accumulated prior to collection, we assumed that there is no stock of waste materials in the environment which is drawn down or permitted to build up depending upon the relative magnitudes of flows into the stock, deterioration of materials contained in the stock, and flows (extraction) from the stock. All "stocks", exist only at "way stations" in the supply process. This assumption rests on the observation that wastepaper which is not accumulated -or collected for recovery as it is discarded, is effectively destroyed for recycling purposes.

A possible exception to this assumption is the storage of old newspapers by households, which may occur at some average level independently of a program of periodic, special collection services. Given a specific time period following the most recent special collection of newspapers. in a prescribed area, it should be possible to estimate the likely magnitude of newspaper stocks which could be acquired with a special collection. The level of these stocks very likely will depend upon households expectations regarding provision and timing of special collection services, among other things.

If periods of high prices and accelerated recovery activities do result in the depletion of these pipeline inventories, then in succeeding periods any given level of supply flows will draw upon pipeline accumulations of lower average size and upon a mix of discard streams of reduced homogeneity. These factors increase collection and processing costs for any given quantity supplied, and reduce the amounts which the industry will choose to supply at any given price. During periods of depressed prices and recovery activity, holding point inventories will build up, and must either be supplied to users at the market price, or disposed of to make way for newly generated waste material.

The supply of paperstock includes substantial quantities of industrial scrap. We used the lagged Federal Reserve Index of production of converted paper products and paperboard containers as a measure of the industrial scrap component of supply. The calculated elasticity of .38 indicates that a one percent increase in this Federal Reserve production index increases the total supply of paperstock by about four-tenths of one percent. This elasticity is about what one would expect, given that industrial scrap comprises roughly this same percentage of total paperstock supply.

Several variables were omitted from the estimated supply equations due to lack of appropriate time series data. One of these, wages of unskilled labor, exhibited in annual series a smooth upward trend over the period in question. There is little evidence to the effect that this source of increased cost in what is a labor intensive industry was offset by the introduction of new technology.

A change in the paper and paperboard output mix may, however, have served partially to offset the effect of increased labor costs. The increase in use of corrugated container products provided an addition to the wastepaper industry's resource base which is easily identified, separated at source, and generated at relatively accessible sites. The growth in paper-using technology in the service sector of the economy contributed further to increased availability, since much of the discard from this site is homogeneous and of high volume.

A trend variable in the supply equation was included to measure these two effects. The variable proved insignificant indicating that the two may be essentially offsetting effects.

IV. CALCULATION OF TAX IMPACTS

The econometric model of the wastepaper market provides quantitative estimates of demand and supply parameters through which a change in tax treatment of virgin fiber resources has its impact on the recycling of wastepaper. These parameters and their estimated values are: the cross-elasticity of demand for paperstock with respect to the price of woodpulp, 0.13; the elasticity of demand for paperstock with respect to own price, 0.16; and the price elasticity of paperstock supply, 0.15. Together these parameters permit calculation of the percentage increase in wastepaper recycling which would follow a given percentage increase in the price of woodpulp.

Our data permit several alternative computations of the impact of capital gains taxation of stumpage profits on the recycling of wastepaper. The first will use the demand and supply elasticities as estimated and the maximum long-run price change in woodpulp attributable to capital gains. The second will assume long-run substitution between woodpulp and wastepaper is perfect (rather than limited by current capital stock and technology), and take supply elasticity and price effects as used in the first computation. The third computation will assume long-run substitution is perfect, take long-run supply elasticity as ten times our short-run estimate, and use a most-likely figure for the tax impact. The third alternative should provide an upper limit to the long-run impact of removing capital gains taxation of stumpage profits on the quantities of wastepaper recycled.

A. Case I

The maximum possible increase in the price of woodpulp which would result from removing capital gains treatment of timber income has been calculated earlier (in Ch. 6) as 4.2 percent. The effect of removing the capital gains provision would be to shift the demand curve for paperstock, increasing the amount of paperstock demanded at each price by 0.13 x 4.2% or .55%. The effect of this shift on the recycling of wastepaper given the supply curve as estimated would be an increase of 0.04 percent. This figure is obtained from a calculation analogous to that presented in chapter 6 to calculate the effect of a supply shift:

Percent change in wastepaper recycled

$$\frac{.55\% \times E_s \times E_d}{E_d + E_s} = \frac{0.55\% \times .15 \times .16}{0.16 + 0.15} = 0.04\%$$

At a present recycling level of close to 12 million tons per year, this translates to a 4,800 ton increase per year.

This is the recycling effect which can be inferred from the empirical basis provided by the econometric market study. The inference rests in part upon the assumption that the underlying structural conditions generating the data from which the parameters are estimated remain the same for the prediction period. The appropriateness of the model as specified and the suitability of the available data used to test the model have been dealt with at length earlier in the discussion of the econometric model and results.

These estimates are based on observations of month-to-month movements in the variables selected to describe the supply and demand relationships. The relationships so described are short-run--and no attempt is made to take account of influences on long-run investment decisions which in turn can alter the technological conditions underlying the industry behavior on both sides of the market.

A feature, of industry technology which prevailed during the test period, and which would have important implications for the substitution possibilities between wood and paperstock--and hence for the pattern of demand behavior exhibited during htis period--is the dominance of industry capacity not equipped to use wastepaper as a fiber source. The present study has not attempted to provide a basis for predicting the possible contribution that a change in federal tax policy might make to redressing this situation. A perceived long-run change in relative costs of alternative fiber sources could affect decisions on incremental capacity in ways favorable to the increased use of secondary fiber.

The impact of such technological developments are not to be relegated solely to the “demand” side of the wastepaper market. Changes in fiber recovery and cleaning, and in paper and paperboard forming processes clearly would affect the necessary characteristics of suitable paperstock inputs, and by thus altering the desired outputs of the wastepaper collecting and processing sector change the availability and accessibility conditions affecting supply potential for secondary fiber. For example, an increased ability to use the shorter groundwood fiber in newspaper or to reduce the importance of contaminants in mixed wastepaper would permit the tapping of relatively abundant materials, much of which is no less accessible than the amounts of similar materials presently being recycled. Impetus to such developments may be provided by the growth of large and diversified solid waste recovery firms and vertical integration of the recovery and manufacturing processes.

Under technological conditions similar to those prevailing during the test period, longer-run elasticities may be greater than those calculated from the estimated model. Particularly on the demand side we would expect greater response to a change in relative prices as existing substitution possibilities are explored and exploited. Once new supplies of paperstock have been located and developed, this fiber source may be expanded in use at the expense of the relatively more expensive virgin woodpulp. On the supply side the longer-run picture is less clear since adjustment efforts to discover and collect additional tonnages of suitable inputs for desired output grades may be hindered by limited resource availability.

B. Case II

This case needs little discussion. The assumption of perfect long-run substitutability between virgin woodpulp and wastepaper is undoubtedly closer to the truth than is our elasticity estimate which is based on short-run responses to changes in market prices. Perfect substitutability would dictate that removal of tax subsidies to woodpulp production would result in price increases for both virgin and secondary inputs equal to the subsidy per unit. Assuming that the subsidy amounts to the full 4.2 percent of the price of woodpulp, the price of wastepaper would rise by this same amount, and the quantities of wastepaper recycled would increase by 4.2% x .16 = 0.67%.

C. Case III

As indicated in Chapter 6, the long-run impact of capital gains taxation on the market price of woodpulp is probably more on the order of one percent than the 4.2 percent used as the maximum possible effect. Assuming that the long-run supply elasticity is ten times our computed .15 estimate, or 1.5, and long-run substitution possibilities are perfect, the impact on recycling would be an increase of 1.5 percent.

CHAPTER 9

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